Concept Engineering:

An investigation of TIME vs. MARKET
orientation in product concept development

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ABSTRACT

This thesis introduces Concept Engineering, the result of an extensive collaborative research effort with product development professionals from member companies of the Center for Quality Management, as a complete decision support process for enhancing product concept development. Concept Engineering applies the principles and practices of Total Quality Management to develop customer-focused product concepts. The simultaneous introduction of Concept Engineering into product development organizations in three different companies created an opportunity for a comparative study of the product concept decision process. The comparative analysis is conducted using Inductive System Diagrams, a method introduced in this research, for systematic field-based hypothesis generation. Inductive System Diagrams combine aspects of grounded theory methods and system dynamics to develop and communicate substantive theories intimately tied to the data. The cross-company comparative analysis of product development teams, some using and others not using Concept Engineering, led to the generation of a dynamic hypotheses regarding the impact of a relative emphasis on TIME vs. MARKET orientation during the product concept decision process. It is proposed that a relative emphasis on TIME reduces concept development time but increases total product development time compared to a relative emphasis on MARKET orientation during product concept development. The MARKET orientation results in design objectives with higher clarity, credibility and stability. TIME orientation led to relatively lower design objective clarity and credibility resulting in product concept changes during downstream development activities thus increasing the total development time.

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Preface

The presentation of this thesis follows the progression of work done in this research effort. In the beginning, there was a desire to investigate the "customer focus" theme of Total Quality Management and it was realized that product development represented a high leverage point in which to conduct this work. A collaborative research effort with product development professionals from member companies of the Center for Quality Management led to the evolution of Concept Engineering as a complete decision support process for product concept development. This material is covered in Chapter 1 and Appendix A .

The introduction of Concept Engineering to product development efforts within the participating companies created an opportunity for a inter-company comparative study. Additionally, as it was not feasible for the participating companies to implement a whole-sale conversion to Concept Engineering, it was possible to conduct an intra-company comparative analysis involving product development teams studying Concept Engineering and those that did not. The design of this research is addressed in Chapter 2.

The research design led to an opportunity to conduct extensive, field-based participant observation of product development activities, in a comparative setting. As a result, it was possible to apply relevant theory generation methods from sociology to the product concept decision process. It was observed that a relative strength of the sociological methods was in the identification of key process variables. However, relative to System Dynamics methodologies for variable integration, the Sociological integration methods were weak. As a result, a marriage of the relative strengths of the two approaches was created in a process called Inductive System Diagrams. This process is described in Chapter 3.

In chapter 4, the hypotheses related to product concept development, developed through the Inductive System Diagram process, are presented in the context of current literature. Based on the generated hypotheses, management diagnostics for the product concept decision process are presented in Chapter 5. Chapter 6 describes potential next steps to continue the development of Concept Engineering, product concept decision theory and Inductive System Diagrams.

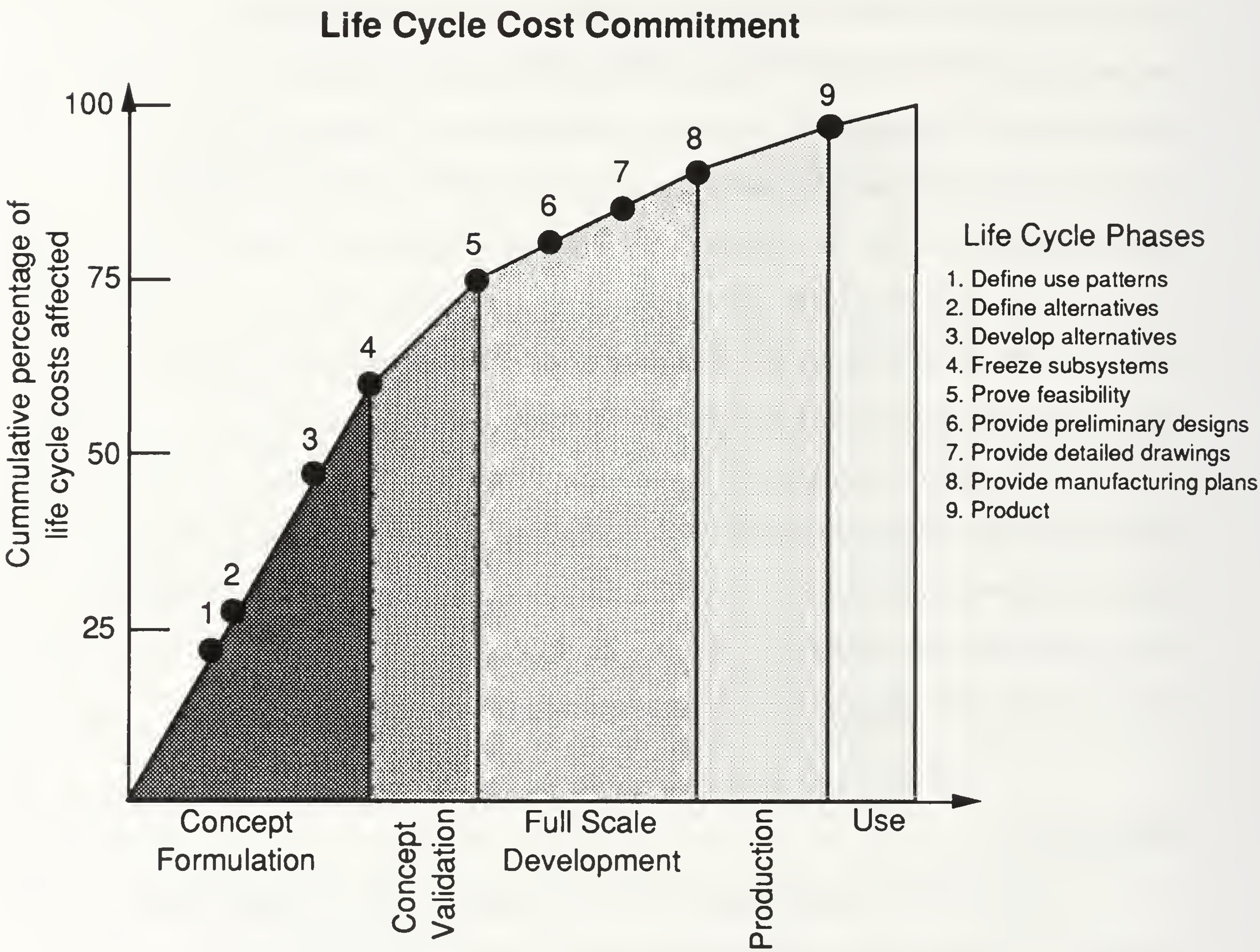
Chapter 1: Concept Engineering

The total quality management (TQM) literature has two dominant themes: continuous process improvement and customer focus. The first theme, continuous process improvement, has a well-established set of methods and tools (7 Steps, 7 Statistical Tools, etc.) that are widely disseminated in practice and academia. (Feigenbaum 1951, Western Electric Co. 1956, Juran & Gryna 1970, Ishikawa 1976, Kume 1985, AT&T 1987, Scholtes 1988, Montgomery 1991) In contrast, the customer focus theme, with the principal exception of Quality Function Deployment activities (Hauser & Clausing 1988, Akao 1990, Griffin & Hauser 1992) is not supported by a similar set of widely accepted tools and methods. However, an emphasis on attending to customer needs as a critical success factor in new product development has been consistently underscored by researchers in the quality literature (Shewhart 1938, Deming 1982, Ishikawa 1985, Juran 1988) and in the product development literature (for example: Rothwell et al. 1974, Cooper & Klienschmidt 1986, Clark & Fujimoto 1991).

Motivation

In Cooper and Klienschmidt's (1986; p.76) study of 252 new product case histories in 123 firms "the weakest rated activities were the 'up front' or pre-development activities, namely initial screening, preliminary market assessment and detailed market study." Supporting this finding, many studies conclude there is potential benefit from research on the product development process, particularly the early activities (Rothwell, et al.. 1974, Cooper & Klienschmidt 1986, Clausing & Pugh 1991, NRC 91, Mahajan &

Wind 1992). Additionally, a recent National Research Council report: *Improving Engineering Design: Designing for Competitive Advantage.* estimates that 70% or more of product life cycle costs are determined during concept design, as illustrated in the figure below (NRC 1991; p.5).



The NRC report concludes the overall quality of engineering design in the United States is poor. Empirical studies of actual product development efforts confirm that critical activities are consistently omitted (Cooper & Klienschmidt 1986, Mahajan & Wind 1992). Additionally, the results of my

own field investigations in this area are consistent with this conclusion; I have heard CEOs of *successful* companies describe their product development process as "random walks with random results" and as a series of "blind alleys" (Burchill et al. 1992). In pursuit of this identified need, Concept Engineering was developed as a process for integrating customer driven requirements into design activities.

Concept Engineering

Concept Engineering is at one level a process for developing product/service concepts that strive to meet or exceed customer requirements; at another level it is a decision support process.[1] This chapter outlines the evolution and essential features of the Concept Engineering process (a complete description is included as Appendix A) and then provides evidence that it is consistent with the requirements of complete decision support processes. A complete decision support process is defined as one that supports the decision maker in all phases of the problem solving process.

Concept Engineering Evolution

Concept Engineering had its genesis in the teachings of Dr. Shoji Shiba, a visiting professor at MIT, in the fall of 1990. Professor Shiba presented several Total Quality Management decision aides in the context of a quality deployment case study. Coupling Shiba's work with Dr. Deming's concept of operational definitions (Deming 1982) led to the outline of a process for

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[1] Although the term Decision Support System has generally been applied to problem-solving assistance systems using computers (Elam, et al.. 1986), there is evidence that pencil and paper delivery systems are just as effective as computerized versions (Cat-Baril & Huber 1987). Therefore, I will use the term Decision Support Process (DSP) to refer to a problem-solving system without the requirement to include computers.

operationally defining customer requirements which the author applied in the development of salt-water flyfishing stripping basket.[2]

A review of the Stripping Basket project by a member of the Operating Committee of the Center for Quality Management[3] (CQM) led to an offer to present this material in the CQM's Six-day TQM Course for Senior Executives in the summer of 1991. This offer blossomed into a two year collaborative effort by representatives of several CQM member companies and MIT to apply the Plan-Do-Check-Act cycle (Ishikawa 1985) to the development of what eventually became Concept Engineering.

Mutual Learning

In the development of Concept Engineering, the company participants were equal partners with the researcher in identifying and evaluating the investigated problems and solutions. Representatives from four companies and MIT were engaged in a continuous relationship over a two year period. The members met collectively to discuss objectives and findings and worked independently pursuing particular assignments. In stretches, often lasting several months, the group met for as much as one full day per week. Interim periods were spent implementing and evaluating the results of previous decisions.

During the evaluation periods, it was not unusual for members of one company to be present in the product development team meetings of other participating companies observing, along side the MIT researcher, the effects of proposed solutions. This level of sharing allowed insights into what

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[2] The stripping basket, which has been patented and licensed, has been reviewed in the New York Times and was widely acclaimed in the flyfishing trade press in 1992 and 1993.
[3] The Center for Quality Management, headquartered in Cambridge MA., is a consortium of over thirty organizations dedicated to the pursuit of Total Quality Management.

worked and didn't work to be rapidly spread among participating companies, i.e., an innovation at one company could be applied at another company usually in the matter of days or weeks at most. (The resulting rapid feedback on process improvement opportunities was a major contributing factor in Concept Engineering's development into a complete decision support process.) The practice of mutual learning and sharing continues as evidenced by two presentations at the February, 1993 Concept Engineering User's Group in which two companies presented innovations and enhancements to the Concept Engineering process (Appendix B).

A significant advantage of practitioner research partners is the ability to focus effort on substantive issues. In this research effort, the problems investigated were those which product development professionals in the firms were facing. "Practitioners often bring the pursuit of irrelevant or ill-conceived lines of inquiry to a rapid halt, correcting or refining the questions asked in ways that lead to sharper formulation and more productive research" (Whyte et al. 1991; p. 54). Additionally, the investment made by the organizations in researching existing problems provides a built-in incentive for implementing the solutions. This model is in sharp contrast to the conventional approach of literature reviews, hypotheses development and subsequent search for an organizational setting for testing (Whyte et al. 1991).

Elden and Levin (1991) describe this process of participative action research as "cogenerative learning". In cogenerative learning, insiders and outsiders bring their respective frameworks (understandings) of events together to create a shared explanatory framework more powerful than any they could have generated independently. Insiders experience the workplace directly and have a great deal of specific knowledge of the setting; this

knowledge is often tacit and not reflected on. Outsiders (researchers) have general knowledge of the field of interest and training in systematic inquiry and analysis techniques. This marriage of specific and general knowledge provides an opportunity for the creation of new substantive knowledge.

Concept Engineering Description

Concept Engineering is a conceptual model, with supporting decision aids, for developing product concepts. The process alternates between the level of thought (reflection) and level of experience (data) (Kawakita 1991) in a way that allows participants to understand what is important to the customer, why it is important, how it will be measured and how it will be addressed in the product concept. Concept Engineering has five stages each with three steps (see figure on the next page). These stages and steps form the road map which outlines the conceptual model underlying our product concept decision process.

The model begins with developing a plan for the entire concept development process and ends with the selection of the product concept to be pursued in subsequent development activities. Within each step, decision aids are provided to assist decision making. In some instances, alternative decision aids were employed and evaluated for apparent effectiveness in providing assistance in the product concept decision process. Effectiveness was determined by a consensus opinion of the participants of the Concept Engineering research team and/or members of actual product development teams. The Plan-Do-Check-Act cycle is continuously applied to the development of the conceptual model and supporting methodologies. A brief description of each stage, as it currently exists, is provided below. Refer to Appendix A for more detailed information.

Concept Engineering

1. Understanding Customer's Environment

Step 1: Plan for Exploration
Step 2: Collect the Voice of the Customer
Step 3: Develop Common Image of Environment

2. Converting Understanding into Requirements

Step 4: Transform Voices into Requirements
Step 5: Select Significant Requirements
Step 6: Develop Insight into Requirements

3. Operationalizing What You Have Learned

Step 7: Develop and Administer Questionnaires
Step 8: Generate Metrics for Requirements
Step 9: Integrate Understanding

4. Concept Generation

Step 10: Decomposition
Step 11: Idea Generation
Step 12: Solution Generation

5. Concept Selection

Step 13: Solution Screening
Step 14: Concept Selection
Step 15: Reflection

Stage 1: Understanding Customer's Environment

The objective of Stage 1 is for the development team to develop empathy for the customer, in the actual use environment of the product or service. Stage 1 consists of developing a plan for the team's exploration, doing the exploration, and using the data collected by the team to develop a contextual anchor from the images of the customers' environment. The creation of this common mental map of the customer's environment is a unique aspect of Concept Engineering.

The planning process begins with an articulation of the project scope. After the scope is outlined, appropriate market segments and customer types are identified for investigation. Prior to visiting the selected customers, the team members develop an open ended interview guide and interview skills. Pairs of team members (usually cross-functional) visit customers and conduct the interview at the customer's site and take verbatim notes of customer comments and their own observations. Upon completion of the interview process, images of the customer's use environment are selected and analyzed with a KJ diagram[4] (Ofuji 1990, Kawakita 1991, Shiba et al. 1991a). This "Image KJ" is a link to the customer's real world and acts as a contextual anchor in the customer's environment for all future product concept decisions.

Stage 2: Converting Understanding into Requirements

Stage 2 distills what was learned from the customer exploration into a small set of well understood, critical customer requirements. In this stage, the Image KJ developed in Stage 1, is used as a contextual anchor in the development of requirement statements to ensure they are consistent with the

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[4] KJ diagrams structure detailed language (vs. numerical) data into more general conclusions using semantic and abstraction guidelines. They are one of a family of tools invented by Jiro Kawakita and known as the KJ method (Kawakita 1991).

customers' environment. A small set of the vital few from the useful many requirements is selected and the relationships between them are analyzed. The process and guidelines for linking customer voices to contextual images and transforming the voices into requirement statements is unique to Concept Engineering.

The transformation process converts the customer's language, often laden with emotion, into a customer requirement statement better suited for use in downstream development activities (Ofuji 1990). Each customer voice is explicitly linked to an image of the customer's environment and through a clearly defined process of successive refinement is developed into customer requirement statements. The entire team then selects the vital few customer requirements from the useful many through a democratic and iterative process[5] of identifying the most important requirements based on their respective understandings of the opportunity. The KJ method (Shiba et al. 1991a) is again employed to develop new insight and team consensus regarding the relationships among requirements.

Stage 3: Operationalizing What You Have Learned

In Stage 3, the goal is to ensure that the key customer requirements are clearly, concisely, and unambiguously communicated in measurable terms. The key customer requirements are validated with customers, operationally defined in measurable terms and the resulting information is displayed in such a way that the relationships between requirements, metrics and customer feedback is easily seen. The application of Kano's analysis, described in detail in Appendix A, to customer requirements is unique in US concept development activities (Kano et al. 1984).

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[5] The Multi-stage Picking-up Method, another of the KJ method tools, focuses on the most powerful statements by eliminating non-candidates in an iterative selection process.

Two validation methods, self-stated importance assessments and Kano's analysis, are employed during this stage to assess customer attitudes towards the selected customer requirements. The self-stated importance questionnaire is a traditional marketing research technique (Griffin & Hauser 1992) and indicates the relative importance of requirements. Kano's analysis (Kano et al. 1984) segregates requirements into four categories (Attractive, One-dimensional, Must-be, and Indifferent) depending on the relationship between changes in functionality and changes in customer satisfaction. Additionally, in Stage 3 the team develops and structures[6] metrics in order to measure, quantitatively, requirement realization. This stage concludes with the development of a Quality Chart and Operational Definitions (Deming 1986, Hauser & Clausing 1988, Juran 1988, Akao 1990) to integrate customer requirement understanding.

Stage 4: Concept Generation

This stage marks the transition in the development team's thinking from the "requirement or problem space" to the "solution space." In this stage the objective is to develop the largest number of potential solution ideas possible. Multiple perspectives of the development project are used to generate ideas from distinct vantage points. The use of a structured idea development process is uncommon in US product concept development.

The complex design problem is decomposed into smaller, independent sub-problems based on the customer's perspective and also from the engineering development perspective. The team creates, through individual and group collaboration efforts, an exhaustive list of ideas (both feasible and unfeasible) for each sub-problem; working first from the customer's vantage

[6] Tree diagram method relates means to ends, which are in turn means to more general ends, in a hierachial relationship (Shiba 1991b).

point before exploring the internal engineering perspective. Generated ideas are systematically reviewed and enhanced. This stage concludes when each team member creates their ideal solution concept from the generated list of ideas.

Stage 5: Concept Selection

In the final stage of Concept Engineering a product concept is selected for downstream development. In this stage, concepts are systematically reviewed, compared, combined and enhanced in an iterative process of concept development. Concepts are evaluated against customer requirements and organizational/environmental constraints.

In the previous stage, the development team generated a wide array of solutions to address collectively the set of customer requirements. In this stage, the team thinks individually and together, seeks expert help, and experiments in the laboratory in an iterative process of combining and improving initial solution concepts to develop a small number of superior concepts. The "surviving" complete concepts are evaluated in detail against customer requirements and organizational constraints in order to select the dominant concept(s). When completed, an audit trail exists for tracing the entire decision process from project scope determination through detailed concept analysis as the Concept Engineering process is self-documenting.

Decision Support Processes

Decision Support Processes are designed to support decision makers in the various phases of problem solving. So far, no generalized problem solving process exists that has been empirically validated (Mintzberg et al. 1976, DeSanctis & Gallupe 1987, Sainfort et al 1990). However, Mintzberg and colleagues in their classic field study (Mintzberg et al. 1976) of 25 strategic

(unstructured) decision processes concluded that the decision process has three phases: identification, development, and selection. Identification consists of both recognition and diagnosis routines. The development phase includes two basic routines: search and design. The selection phase consists of screening, evaluation-choice and authorization routines. Furthermore, the Mintzberg study identifies three sets of supporting routines: decision control, communication and political activities, which facilitate the three major phases of the decision process.

In the context of the product concept decision process, Mintzberg et al. (1976) empirically developed problem solving process can be redefined to be: *requirement* identification, *idea* development, and *concept* selection. I will use this framework to illustrate how Concept Engineering is a complete Decision Support Process[7], the table below outlines the relationships which are described in subsequent paragraphs.

Decision Phase	C.E. Step	Decision Aid
Identification	1	Customer Selection Matrix
- recognition	2	Interview Guidelines
- diagnosis	3	Image KJ
	4	Transformation Process &
	5	Guidelines
	6	Multi-stage Picking-up Method
		Requirement KJ
Development	7	Self-stated Importance Assessment
- search		Kano's Analysis
- design	10	Multiple Design Decomposition's
	11	Idea Generation Process
	12	Solution Concept Generation
Selection	13	Screening Matrix
- screen	14	Selection Matrix
- evaluation-choice		Self-documenting Audit Trail
- authorization		

[7] This argument could also have been made with alternative descriptions of the problem solving process, i.e., Sainfort et al. 1990, MacKay et al. 1992.

Mintzberg et al. observed that the identification phase consists of both recognition and diagnosis activities. They defined diagnosis as "the tapping of existing channels and the opening of new ones to clarify and define the issues" (p.254). Concept Engineering provides conceptual and methodological guidance for clarifying and defining the issues. Stages 1 and 2 deal explicitly with exploring the market and converting the knowledge gained in the exploration into a well-defined and focused set of customer requirements. Specifically, in Stage 1, Understanding the Customer's Environment, a "Customer Selection Matrix" is developed to identify exploration arenas; this matrix explicitly includes past, present and prospective customers. Next, "Interview Guidelines" are developed to assist the focus of the exploration efforts. Stage 2, Converting Understanding into Customer Requirements, provides clear guidance in the form of "Translation Guidelines" and "Transformation Worksheets" for converting the Voice of the Customer information gathered in Stage 1 into unambiguous and nonrestrictive Customer Requirements Statements. The vital few requirement statements are identified using the Multi-stage Picking-up Method and structured using the KJ diagram (Kawakita 1991, Shiba et al. 1991a).

The Development Phase observed by Mintzberg et al. consists of both search and design routines. They indicate four different kinds of search behavior: memory, passive, trap and active. In Stage 3, Operationally Defining Requirements for Downstream Development, the requirements developed and selected in Stage 2 are actively validated with potential customers through the use of Self-Stated-Importance questionnaires and Kano questionnaires. The Idea Generation step in Stage 4, Concept Generation, could conceivably incorporate all four types of search activities. The Mintzberg study identified design activities that result in either custom-

made or modified solutions. The concluding step of Stage 4 is the generation of custom-made solutions that address the set of customer requirements. It is possible that constraints imposed on the design team could limit idea generation, and thus solution generation, to existing solutions which would result in "modification" design activities.

The Mintzberg study identified three routines in the Selection Phase: screen, evaluation-choice, and authorization. The first step in Stage 5, Concept Selection, is Solution Screening. In this step a "Screening Matrix" is employed to reduce the number of alternatives to a smaller number of feasible alternatives. Additionally, each proposed solution is evaluated against the customer requirements relative to a pre-selected datum. In the second step of Stage 5, Solution Selection, a more analytical comparative process is introduced, if necessary, to further assist the development team in identifying the dominant concepts. Authorization, the final routine observed by Mintzberg et al. in the Selection Phase is not specifically addressed in Concept Engineering. However, each step of Concept Engineering is self-documenting; some development teams have used their Concept Engineering working documents in their project proposal presentations before management authorization committees.

The three routines that support the three central phases of the decision process observed by Mintzberg et al. are: decision control, communication, and politics. The decision control routine consisted of two basic activities: planning and switching. Decision planning consists of "a rough schedule for solution, a development strategy, and an estimate of the resources" (p.261). The Concept Engineering process is described with a flow chart outlining a coordinated set of conceptual steps. Furthermore, in the introduction to the Concept Engineering Manual (Burchill et al. 1992) a Gantt Chart displaying

the various activities and estimated completion times is provided to assist in project planning. Switching "directs the decision maker's attention to the next step, to choosing the appropriate routine, such as diagnosis or search,..." (p.261). With respect to switching, the Concept Engineering manual also provides checklists at the end of each step to assist in determining if a minimum set of observable conditions has been met before moving to the next set of activities.

The Decision Communication routines observed by Mintzberg et al. include: exploration, investigation and dissemination. Exploration is described as a general or passive search for information. The investigative routine involves the focused search and research of special-purpose information. Dissemination involves communication of information about the decision process progress or outcome to ensure eventual acceptance. Concept Engineering is geared towards investigative information searches in that the objective and recommended information processing approach are clearly established for each step of the process. Concept Engineering facilitates dissemination by having clearly defined switching points and criteria and the self-documenting nature of the tools mentioned previously.

According to Mintzberg et al. political activities "reflect the influence of individuals who seek to satisfy their personal and institutional needs by the decisions made in an organization" (p.262). This is consistent with Salancik and Pfeffer's (1974) view that power is used in organizations to influence decisions concerning the allocation of resources; the more scarce the resource the less objective criteria and the more power will be used in obtaining it. Additionally, Salancik and Pfeffer state that when there is a disagreement about the priorities and consequences of possible actions, decisions can not be rationalized. Hickson et al. (1971) propose that "preventive routinization"

reduces or removes uncertainty and thus reduces opportunities for the use of power. Concept Engineering, which assists all stages and supporting routines of the decision process, removes uncertainties, clarifies priorities and the relationships between potential actions and objectives. This in turn, increases the likelihood for rational decision making thus reducing the opportunity for political activities.

Conclusion

Concept Engineering is a conceptual model with supporting tools and techniques. Furthermore, in relation to the empirical decision structure outlined by Mintzberg et al. (1976), Concept Engineering addresses not only each phase of the product concept decision process (requirement identification, idea development, and concept selection) but also each of the supporting routines (decision control, communication, and politics). In these respects it should be considered a complete decision support process.

The development of Concept Engineering, particularly given the active participation of corporate product development professionals, provided an opportunity to conduct a comparative study of product concept development activities. Chapter 2 outlines the research objectives, design and subsequent implementation. Chapter 3 presents Inductive System Diagrams as a method for developing and articulating grounded, substantive theories for the product concept decision process. Chapter 4 presents the evidence, inferences and propositions related to management choices in the product concept decision process. Chapter 5 outlines management diagnosis opportunities of product concept development. Chapter 6 summarizes the findings and outline potential future directions.

Chapter 2: Research Design

This research was designed to develop a substantive theory to help clarify the product concept decision process and for generating data related to the effectiveness of Concept Engineering as a method for developing product concepts. A key ingredient for developing both the theory and the method was the use of comparison groups. By comparing similar and dissimilar groups we could more readily identify key concepts. However, I recognized that if some of the comparison groups were stacked in favor of success or failure, the conclusions reached could be misleading at worst and delayed at best. As a result, I requested randomization controls to address much of this bias to provide a stronger foundation upon which to build the method and theory.

In the proposed design, each of three participating companies would identify two pairs of development teams. Each pair would be approximately similar in scope, demographics, and history. One team from each pair would be randomly assigned to use the Concept Engineering process while the other team would use Pugh's Concept Selection process (Pugh 1981) which is similar to Stage 5 of the Concept Engineering process.

The progress and outcome of the research would be assessed in three ways. First, field research techniques for observations, interviews and survey instruments would be employed to develop an understanding of how and why Concept Engineering works. The specific questions pursued were expected to change over the course of the research, but based on an exploratory cause-and-effect diagram (figure 2.1) they would center around the concepts of: structured design process, clear customer requirements, and organizational commitment.

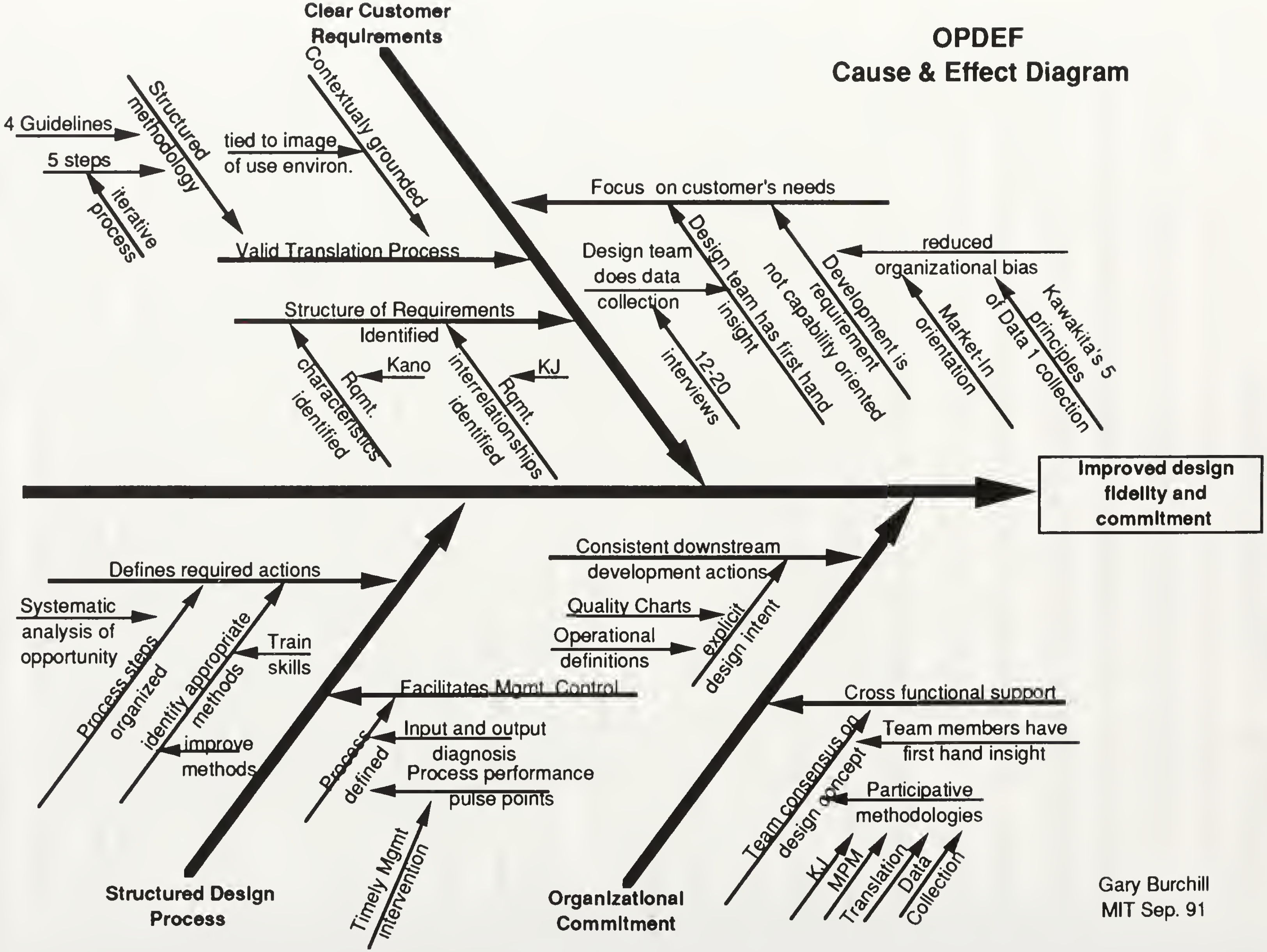
OPDEF
Cause & Effect Diagram
Clear Customer Requirements
4 Guidelines
5 steps
iterative process
Structured methodology
tied to image of use environ.
Contextualy grounded
Valid Translation Process
Structure of Requirements Identified
Kano
Rqmt. characteristics identified
KJ
Rqmt. interrelationships identified
Focus on customer's needs
Design team does data collection
12-20 interviews
Design team has first hand insight
Development is requirement not capability oriented
reduced organizational bias
Market-In orientation
Kawakita's 5 principles of Data 1 collection
Improved design fidelity and commitment
Structured Design Process
Defines required actions
Systematic analysis of opportunity
Process steps organized
identify appropriate methods
Train skills
improve methods
Facilitates Mgmt. Control
Process defined
Input and output diagnosis
Process performance pulse points
Timely Mgmt intervention
Consistent downstream development actions
Quality Charts
Operational definitions
explicit design intent
Organizational Commitment
Cross functional support
Team members have first hand insight
Team consensus on design concept
Participative methodologies
KJ
MPM
Translation
Data
Collection
Gary Burchill
MIT Sep. 91

figure (2.1)

Second, objective process measures developed by the CQM Research Committee (CQM 1992) would be used at both the requirement generation and concept selection stages. Finally, subjective assessments by relevant company officers would be made of the performance of each team.

Validity Threats

Every research design should attempt to preclude as many validity threats as possible. Internal validity represents the degree of confidence that the input changes actually caused the observed outcomes. External validity reflects the degree of confidence that the results can be generalized to groups other than those studied. Construct validity addresses how well the research measures what was intended to be measured (Cook & Campbell 1979, Kidder & Judd 1986). The design outlined above, and agreed upon by representatives (a chief operating officer, a general manager and a director of product development) of the participating companies, attempted to minimize each of these validity threats.

External Validity

The nature of the companies participating in the study necessarily imposes some threats to external validity, or the ability to generalize the findings. Specifically, all of the Concept Engineering teams were fairly small, core teams of six to eight members; although the full development team could be substantially larger. Additionally, all participating companies considered themselves to be "high-tech" and were members of the Center for Quality Management (CQM). Membership in the CQM requires a strong CEO commitment to Total Quality Management (TQM) and there is considerable training and emphasis on the use of many of the techniques (e.g. KJ diagrams,

Tree Diagrams) employed in Concept Engineering. Additionally, TQM emphasizes standardization and process orientations which may have affected the acceptance of the process by development team members. Finally, the design techniques introduced in this study represent only a small subset of the potential development process enhancements. These factors limit the ability to generalize the conclusions of the study.

Construct Validity

The principle of triangulation, well known in navigation, applies to research as well. At sea, any three measures of location taken by different methods, i.e. satellite versus radar, will position you at three different points on the map. Your true location is more likely to be within the triangle formed by the three points than exactly at any one point. Articles and text books on research methodology emphasize the importance of having multiple ways of measuring the constructs of interest (Cook & Campbell 1979, Kidder & Judd 1986, Blackburn 1987, Jick 1979). In the research design of this study, multiple assessment methods, some qualitative and some quantitative, were identified for use.

Internal Validity

This design was structured to address many potential threats to internal validity in order to increase the degree of confidence that the process changes actually caused observed changes in the outcomes, if any.

Compensating Treatment

Some threats to internal validity, which could be present in any study that supplies a favorable treatment to one group and not to the other, revolve around the reaction of the "no-treatment" group. On the one hand, they

could try harder than usual through a heightened sense of rivalry, and on the other they could become demoralized and not work as hard. An accepted device for addressing these threats is to provide the "no-treatment" group with some form of treatment (Cook & Campbell 1979, Kidder & Judd 1986, Blackburn 1987). In this study we intended to provide the non-Concept Engineering groups with Pugh's Concept Selection process (Pugh 1981). Pugh's process would be recognized as a development process enhancement in each of the participating companies.

Experimenter Expectancies

An additional threat to the validity of the study comes from the expectations of the person delivering the intervention. It has been shown that the administrator of the intervention can unwittingly bias the results provided by subjects (Cook & Campbell 1979, Kidder & Judd 1986). In this study, a graduate student was hired and trained as a research assistant to collect data on some of the teams. The research assistant was not provided with training in Concept Engineering and thus could provide a control against some forms of bias which may have been introduced by the author.

Randomization

The importance of randomizing treatment assignment was a critical component of the design's defense against the various threats to internal and external validity inherent in this study. Specifically, given the availability of concurrent, co-located control groups, many threats to validity, such as history (events that occur during the experiment unrelated to the treatment), testing (the impact of the measurement or observation process on the subjects), and instrumentation (the process of collecting data), could be compensated for through the design. However, the presence of a control group does not address the threat to validity from selection, the process used

to assign groups to a treatment condition. Without random assignment of conditions, the selection threat opens the door to a multitude of plausible rival hypotheses which could account for any observed differences. (Cook & Campbell 1979, Kidder & Judd 1986, Blackburn 1987)

Research Implementation

The actual implementation fell far short of the research design. While this clearly has implications for validation efforts originally designed for the study, it did not seriously disrupt the research objective of developing a grounded, substantive theory for the product concept decision process. However, the trials and tribulations experienced in this study are valuable in highlighting some of the difficulties associated with experimental research designs in organizational settings.

All three companies that agreed to participate in the study in the fall of 1991 sent representatives to the two-week training session in January 1992. One company (hereafter referred to as Company 1) began their first Concept Engineering effort in February 1992, the second company (Company 2) began their first Concept Engineering team in April 1992, and the third (Company 3) began in May 1992. It was immediately obvious that the first teams were not assigned on a random basis. In Companies 1 and 2 the appropriate managers selected an initial team they felt had a high likelihood of success. In Company 3, although it was not immediately apparent, the selection and staffing of the first team created a high likelihood of failure. This conclusion is validated by comments from senior managers in Companies 1 and 2 who specifically stated that they needed an initial success and in comments from a vice president of engineering in Company 3, who "felt" Concept Engineering was a ploy by Marketing to shift their work to Engineering. In short, random

assignment to address some of the traditional threats to validity (selection, maturation, etc.) did not take place in this study.

The original design assumed that many teams would be working simultaneously; the calendar time associated with each team was expected to be approximately four months. In execution, each company started the first Concept Engineering effort and then waited for preliminary results before committing itself to support a second team. Furthermore, each team took about six calendar months to complete its work. This delay had enormous implications for the scope of the research given the available time of the primary researcher. In hindsight, it became clear that companies would be hesitant to commit a second team until the first team could be evaluated, at least provisionally. The length of time required for each team to complete its work was a surprise. The largest contributing factor to the increase in project time was delay time before starting. Once the decision was made for a team to apply Concept Engineering, several months might pass before meaningful effort was applied to the project. This was primarily due to other project commitments of team participants. This problem resulted in fewer Concept Engineering teams to be available for the study than had been intended in the design.

With respect to the control groups, the first and second companies also provided a non-Concept Engineering comparison team in the spring of 1992. These teams were assigned on the basis of availability rather than on matching characteristics of scope, demographics, etc. In company 1, the comparison investigation was short-lived; the project literally exploded in the laboratory after two months. Subsequently, in Company 1, the division director was impressed enough with the results of the first Concept Engineering development team that he declared that all subsequent

sponsored development efforts would use Concept Engineering. In company 2, the investigation of the comparison team (not well matched in scope) did proceed through to design approval, although the team did not use Pugh's concept selection process. In company 3, the chief operating officer carried out an extensive study (an entire week, including the weekend, of his time) of Concept Engineering and declared that all company-sponsored development efforts would be required to use it in order to proceed through the company's Product Review Board process. As a result of these differences in approach in the three companies, the study of matched comparison groups called for in the research design did not materialize.

Ultimately, the number and nature of cases investigated was significantly fewer than anticipated. Therefore, any attempts to evaluate the relative effectiveness of Concept Engineering are now subject to considerable threats from rival plausible hypotheses. However, I was able to observe extensively five development teams in four companies that used Concept Engineering and two development teams in two companies that did not. In addition, in Companies 1 and 3, it was possible to make historical comparisons with the previous project completed by development teams assigned to use Concept Engineering. For each development team studied, I typically attended every scheduled meeting, approximately 80 hours per team, and conducted two to three in-depth open-ended interviews with each member of the team and their managers; each interview lasting at least one hour. Therefore, although they lacked random assignment, the available teams did provide a rich comparative setting, with many similarities and dissimilarities, to explore for theory generation.

The Theory Generation Study

In theory generation research, data collection and analysis are conducted concurrently (Glaser & Strauss 1967, Barton & Lazarsfeld 1969, Miles & Huberman 1984, Schein 1987). "Qualitative research in general and theory generation in particular, is essentially an investigative process, not unlike detective work. Observing one class of events calls for a comparison with a different class. Understanding one relationship reveals several facets which have to be teased out and studied individually. The theory is developed in large part by contrasting, comparing, replicating, cataloguing, and classifying the subject of the study" (Miles & Huberman 1984; p.37). Without joint data collection, coding, and analysis, the subtleties in the area of study, and opportunities to investigate them, can be lost. As a result, the evolving nature of desired information precludes the establishment of detailed, pre-specified sampling plans (Glaser & Strauss 1967, Barton & Lazarsfeld 1969). In the words of C.I. Lewis (1929) "Knowledge begins and ends in experience; but it does not end in the experience in which it began."

Glaser and Strauss (1967) make an additional distinction between sampling required for theory development and theory verification. Theoretical sampling, sampling designed to develop rich comparative settings, is conducted to identify and investigate variables and their interrelationships in the development of theory. Statistical sampling is conducted to collect evidence to be used in descriptive or verification studies. As a result, they state that the researcher generating theory need not use random sampling techniques.

Participant Observation

Forrester (1992; p.57) states the professional literature emphasizes how decisions should be made rather than how they are made and "there is not yet an adequate literature on what constitutes the practice of identifying decision-making policy." Forrester's observation on the general decision making process is consistent with specific research findings on the product development decision process which consistently identify large differences between product development theory and practice (Cooper & Klienschmidt 1986, Gupta & Wilemon 1990, Mahajan & Wind 1992). In Forrester's view (1992; p. 52), "perceptive observation, searching discussions with persons making the decisions, study of already existing data, and examination of specific examples of decisions and actions all illuminate factors that influence decisions."

"Technically a 'qualitative observation' identifies the presence or absence of something, in contrast to 'quantitative observation,' which involves the degree to which some feature is present" (Kirk & Miller 1990; p.9). Participant observers gather data in the daily life of the organization studied (Becker 1969). Two approaches to participant observation were combined in this research, grounded theory and action science. In grounded theory, the goal is to develop theory, intimately tied to the data, which explains, interprets and predicts what is happening in an area of investigation (Glaser & Strauss 1967; p.). The action scientist has as a goal, the development of theoretical constructs simple enough to be usable while enabling the actor to grasp all the relevant features of the situation (Argyris et al. 1985; p.78). This strategy has provided the opportunity to generate a substantive theory, intimately tied to actual practice, which provides insight and access to practitioners in the development of product/service concepts.

Action Science

In action science, the emphasis is on obtaining or improving basic knowledge while solving practical problems.[1] Action science subscribes to the view that one of the best ways to understand the world is to try to change it. This perspective leads to a direct challenge of the normal science premise that the primary objective of science is to describe reality. However, action science does subscribe to several features of normal science including intersubjectively verifiable data, explicit inferences, disconfirmable propositions and public testing (Argyris et al. 1985).

One of the primary goals of the action science perspective is to distinguish between espoused theories and theories-in-use. Espoused theories are those that an individual claims to follow. Theories-in-use are those that can be inferred from action. The objective is to make explicit the largely tacit propositional logic of the form "In situation *s* (as the actor constructs it), do *a* to achieve consequence *c*." This means that the research must elicit data on what individuals actually say and do as they interact, as well as data on what they are thinking and feeling at the time of their actions (Argyris, et al. 1985; p.). The ability of the researcher to recognize the possibility for inconsistencies between theories-in-use and espoused theories depends in many respects on the familiarity of the researcher with the daily life of the organization; hence the importance of the participant observation research approach.

The action science requirements for disconfirmable propositions and public testing ask that propositions or hypotheses be characterized by features that allow practitioners to disconfirm them. These include making

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[1] By analogy, this is similar to the early Operations Research work during World War II (Argyris, et al.. 1985).

propositions public, providing the directly observable data on which they are based, making them connectable to these data, and designing conditions conducive to testing them for validity (Argyris et al. 1985; p.233). Edgar Schein in his monograph, "The Clinical Perspective in Fieldwork" (Schein 1987; p.29), states that the clinician typically starts with an "action research" model i.e. the assumption that one cannot understand a human system without trying to change it. As a result, the clinician learns about some of the most fundamental dynamics that operate in organizations, and the power of such work is its ability to provide better variables and better understanding of system dynamics than other research methods. This leads to the conclusion that perhaps the best use of clinical work may be in the construction of variables and theoretical models (Schein 1987, Blanck & Turner 1987).

Grounded Theory

Grounded theory approaches to generating hypotheses are characterized by the use of an exhaustive (and exhausting) data-coding and memo-writing regimen, as well as the use of the constant comparison method of analysis. A grounded theory development process generally consists of the following activities:

1) The researcher starts by coding each incident in his data for as many categories of analysis as possible. While coding an incident, the researcher attempts to compare this incident with all other incidents in the same category.

2) The researcher regularly stops to record in "theoretical memos" his or her thoughts on the developing theory.

3) As the coding continues, the unit of comparative analysis changes from comparison of incident with incident to comparison of incident with the accumulated knowledge of the category.

4) The accumulated knowledge is integrated into a unified whole.

5) The theory is solidified as major modifications become fewer, non-essential categories are pruned, and higher level concepts are abstracted from the detailed categories previously developed from the data (Glaser 1965, Glaser & Strauss 1967, Glaser 1978, Strauss 1987).

Constant Comparison Method

In the constant comparison method, the objective of the sampling process is to allow for comparisons of differences and similarities among the units of analysis. This process of analyzing the similarities and differences produces the dense category development essential to well grounded theory generation. Minimizing differences among comparison groups increases the likelihood that a lot of information is available for developing of the basic properties and conditions of a category. Identifying similar data under comparison conditions of maximum differences identifies the fundamental explanatory variables. To integrate these variables into theory requires investigating the causes, consequences and constraints of these variables also under comparison conditions of maximized differences (Glaser & Strauss 1967; p56-58).

Variable Development

One of the strengths of grounded theory methods is the coding process for category development (Glaser & Strauss 1967, Glaser 1978, Strauss 1987). "The code conceptualizes the underlying pattern of a set of empirical

indicators within the data. Coding gets the analyst off the empirical level by fracturing the data, then conceptually grouping it into codes that then become the theory which explains what is happening in the data" (Glaser 1978; p.55). The process begins with "open-coding", a line by line analysis of the data which is diametrically opposite to the process of coding with preconceived codes. In open-coding the analyst attempts to code the data in as many different ways as possible. The analyst constantly looks for the "main theme", for what appears to be the main concern of or problem for the people in the setting (Strauss 1987; p.35). As the analyst's awareness of the central problem(s) emerges, they alternate open coding with very directed "axial coding". Axial coding consists of analysis done around one category at a time. As core variables begin to emerge, the analyst employs "selective coding" to focus coding to only those variables that relate to core variables in sufficiently significant ways to be used in parsimonious theory. In all 10 to 15 codes are typically enough for a monograph on a parsimonious substantive theory (Strauss 1987; p.32).

Theory Generation Research Validity

In verification research to test a hypothesis, the investigator must already know what it is they are going to discover (Kirk & Miller 1990). In theory generation research, by definition, the researcher does not know what they are going to discover. The relatively small sample sizes and lack of reliance on random sampling techniques associated with the theoretical sampling requirements of grounded theory methods generate conflict with many of the traditional tests of validity outlined by Cook and Campbell (1979). As a result, a fundamental issue of theory generation research is how to express the validity of the developed theories.

Glaser and Strauss (1967) discuss the four properties any grounded theory must have for practical application. The theory must fit the substantive area in which it will be used — the concepts and hypotheses supplied by the theory are closely tied to the data. Second, it must be readily understood by people in the area — it will make sense to the people working in the area. Third, it must be sufficiently general to be applicable in diverse situations — the level of abstraction must be sufficient to make a variety of situations understandable but not so abstract as to be meaningless. Finally, the theory must allow the user partial control over structure and process — the theory must contain sufficient concepts and their plausible interrelations to allow a person to produce and predict change. In short, the theory can be, and is, used by practitioners to guide what they do.

Argyris, et al.. (1985) also propose four criteria for testing the validity of a theory. First is intersubjectively verifiable data — competent members of the scientific community should be able to agree at the level of observation, even if they disagree at the level of theory. The second criterion is explicit inferences — the logic that connects theory and observation should be explicit. Third is the use of disconfirmable propositions — the results of observations must relate to the acceptance or rejection of the theory. Finally is the concept of public testing — the users of a theory test its validity by comparing actual and predicted consequences following a change in their actions based on the research.

From the Clinician's perspective Schein (1987) states that the validity of a theory can be determined by its ability to predict the response to an intervention. The ethnographic view of validity emphasizes the issues of replication and internal consistency (Van Maanen 1983).

Walter Shewhart, the acknowledged developer of statistical process control, may have said it best when he wrote: "there is an important distinction between valid prediction in the sense of a prediction being true and valid knowledge in the sense of a prediction being justifiable upon the basis of available evidence and accepted rules of inference" (Shewhart 1938; p.). Shewhart (1938) points out that it is possible for predictions to be valid even when the knowledge supporting them is not. Similarly, valid inferences can be made from faulty evidence. Therefore, if theories result in testable predictions, then the validity of theory generation research can be judged on the basis of its evidence, inferences and predictions.

Revisiting the validity criterion outlined above it would appear that Schein is concerned primarily with prediction. Van Maanen's concerns seem related to evidence and inferences. Glaser and Strauss appear to address evidence and inference but not prediction; in addition they are concerned with generalizability and user accessibility. Argyris, et al. appear to address evidence, inference and prediction. These observations are summarized in the table below.

Glaser & Strauss	**Argyris, et al..**	**Van Maanen Schein**	**Shewhart**
Fit	verifiable data	replication	evidence
Understanding	explicit inferences	internal consistency	inferences
	disconfirmable propositions	prediction	prediction
****	public testing		
allows for control	****		
general applicability			

These three concepts: evidence, inferences and predictions, constitute a set of requirements which, if addressed in theory generation research, would allow researchers to observe and distinguish both the validity of the hypotheses (predictions) and the validity of the theory creation process

(evidence and inference). An important caveat is drawn from Kuhn's (1962) arguments on how paradigms affect our abilities to interpret the arguments of others, i.e. because we interpret issues from our paradigm not others, it will be difficult for distinct schools of thought to agree on whether any given piece of "knowledge" is valid because the accepted rules of inference are different. However, at a minimum, it should be possible to assess whether the hypothesis or prediction itself is valid.

Finally, although not essential from a validity perspective, I would also encourage researchers to strive for user accessibility as a criterion for substantive theory construction. For practitioners to use a theory they must understand how variables under their control relate to the system of interest; if a theory describes a system without providing practitioners access it won't be used.

Conclusion

The original design had accommodations to many recognized threats to validity, but in the execution of the research the researcher was unable to ensure that the research was implemented as designed. A researcher simply does not have sufficient influence to control the operational requirements of organizations. On the other hand, the research project still provided a valuable opportunity to conduct detailed investigations of the development process in a comparative setting. This environment supports the goal of generating a substantive, grounded theory to provide leverage to practitioners in clarifying the product concept decision process. However, the methodologies appropriate to exploring this setting are not widely accepted as mainstream operations management (or social science) research methods.

Chapter 3: Inductive System Diagrams

Social scientists, over the past sixty years, have developed methodologies to generate theory through an inductive process based on the intensive analysis of a small number of data sources. However, a difficulty associated with these, and most styles of qualitative theory development, is conveying credibility. The researcher usually presents only enough data to project credibility which is often not enough to allow for verification by others. A theory which is not clearly stated, and not well integrated, has a reduced likelihood of being accepted (Glaser 1965).

Inductive System Diagrams combine aspects of Grounded Theory methods and System Dynamics. Grounded theory approaches are used to develop the variables which have a great deal of explanatory power and are intimately tied to the data. The cause and effect relationships among these variables are then shown using causal-loop diagramming techniques from System Dynamics. This combination of grounded theory and causal-loop diagramming allows researchers to generate and communicate substantive theories intimately tied to the data.

Grounded Theory

Grounded theory approaches to generating hypotheses are characterized by the use of an exhaustive (and exhausting) data-coding and memo-writing regimen, as well as the use of the constant comparison method of analysis. In the constant comparison method, the objective of the sampling process is to allow for comparisons of differences and similarities among the units of analysis. This process of analyzing the similarities and differences produces the dense variable development essential to well

grounded theory generation. Minimizing differences among comparison groups increases the likelihood that a lot of information is available for developing of the basic properties and conditions of a variable. Identifying similar data under comparison conditions of maximum differences identifies the fundamental explanatory variables. To integrate these variables into theory requires investigating the cause, consequences and constraints of these variables also under comparison conditions of maximized differences (Glaser & Strauss 1967; p56-58).

Variable Development

One of the strengths of grounded theory methods is the coding process for category development (Glaser & Strauss 1967, Glaser 1978, Strauss 1987). "The code conceptualizes the underlying pattern of a set of empirical indicators within the data. Coding gets the analyst off the empirical level by fracturing the data, then conceptually grouping it into codes that then become the theory which explains what is happening in the data" (Glaser 1978; p.55). The process begins with "open-coding", a line by line analysis of the data where the analyst attempts to code the data in as many different ways as possible. As the analyst's awareness of the central problem(s) emerges, open coding alternates with very directed "axial coding". Axial coding consists of analysis done around one category at a time. As core variables begin to emerge, the analyst employs "selective coding" to focus coding to only those variables that relate to core variables in sufficiently significant ways to be used in parsimonious theory. In all 10 to 15 codes are typically enough for a parsimonious substantive theory (Strauss 1987; p.32).

Open Coding

By definition in theory generation research, the essential variables are not known; open coding is the start of the variable development process. During open coding each sentence is explored for as many possible concepts as possible. When coding the concept, it is assigned a variable name which is closely linked to the supporting data. Questions related to the occurrence of the concept are generated. These generative questions build sensitivity for future use in making comparisons when the next occurrence of the concept is encountered (Glasser 1978, Strauss 1987). An example, from my field notes is provided below:

> *"This was a decision node in the conception of the product which was not made by systematic analysis." - R&D manager*
>
> <u>Decision node</u>. What is a decision node? How many are there? What are the necessary conditions for an event to be considered a decision node? Who initiates the decision? Who ratifies the decision? Who monitors them?
>
> <u>Conception</u>. When is a product conceived? What is the gestation period like? I can think of lots of analogies here, prenatal care, miscarriages, etc. ...
>
> <u>Systematic Analysis</u>. What constitutes systematic? unsystematic? When does one favor one over the other? Assuming systematic is preferred; how does one get away with unsystematic analysis?

The open coding process generates a large number of variables quickly. Therefore it is necessary to reduce codes in use. The reduction occurs through a process of abstraction (Hayakawa 1990). In abstraction, variables which convey similar concepts are grouped together and a variable name, which

captures the essence of the common concept, is selected to be used in all references to this concept. In some cases, one code in the grouping represents the best label for the concept and it can be used for the variable name. In other cases, it is necessary to create a variable name which captures the common concept. In the example below, systematic analysis was selected as the variable name which best captured the common concept in all six codes.

systematic analysis
- design constraint tradeoff
- performance comparisons
- conscious dimension sacrifice
- tradeoff equation
- doing homework

By investigating events under similar conditions, those concepts which are common in different settings represent the initial pool of potential explanatory variables. (It is highly probable that the final set of variables could be substantially different than the initial set.) Axial coding is used to develop better insight into these variables.

Axial coding

Axial coding represents an attempt to identify the causes, consequences and constraints of a variable under investigation. It is designed to build substantial knowledge about the selected variable and other variables it relates to (Glasser 1978, Strauss 1987). In studies where both participant observations and interviews are conducted, it can be very productive to conduct a "Causes, Consequences and Constraints" structured interview with participants as soon as possible after observation of the concept of interest. Reviewing existing field notes for evidence of causes, consequences and constraints can also be productive as the following example shows:

"Going back and doing the correlation effort yielded the same numbers and is documented. This gives us triple verification of what we are doing. So I'm willing to sign." - design engineer

<u>Systematic Analysis</u> **causes** <u>Traceability</u> **causes** <u>Confidence</u>

Selective Coding

When a variable begins to stand out as being the core category, as having extra-ordinary explanatory power, it is selected for focused coding. Coding activities are focused exclusively on the selected variable and the other variables with which it has significant relationships. All available data should be considered for review in selective coding (Glasser 1978, Strauss 1987). In this study, the KJ method (Kawakita 1991, Shiba et al. 1991a) was used to investigate core variable relationships, (see Appendix D for examples.)

Iteration

Cycling back and forth between open, axial and selective coding occurs regularly early in the investigation and gradually decreases as the research progresses (Glaser & Strauss 1967, Strauss 1987). For example, at any time during this process insight regarding the variables or related inferences may occur. When this happens, immediately stop and write a "theoretical memo" before continuing or at a minimum make an appropriate annotation in the field notes as shown below (Glaser 1965, Glaser & Strauss 1967, Glaser 1978, Strauss 1987).

"It is becoming increasingly important because this process is taking a long time, not just a long elapsed time because it is not calendar time, but in terms of people time it is extensive" - marketing manager

<u>Systematic Analysis</u> **causes** <u>Labor Requirements</u>.
Memo: <u>Labor Availability</u> **constrains** <u>Systematic Analysis</u>

The insight (**captured in writing first**) can trigger a change in coding strategy. In the example above, the data show evidence that Systematic Analysis causes Labor Requirements. A logical inference, not supported by the evidence, is that Labor Availability could constrain Systematic Analysis. Accordingly, additional theoretical sampling and/or more open coding connected to the concept of labor could follow from this insight. In another example, an integrating diagram can be developed on the basis of axial coding. Analysis of preliminary diagrams can (often) identify inferences regarding variable relationships which are not supported by available evidence. This can trigger additional theoretical sampling, open coding and/or axial coding as required to explore the proposed relationship.

System Dynamics

Forrester (1968; p.1-2) argues that a "structure (or theory) is essential if we are to effectively interrelate and interpret our observations in any field of knowledge." A hierarchical framework for identifying the structure of a system has been identified and developed in the system dynamics field (see for example: Forrester 1968, Goodman 1974, Randers 1980, Richardson and Pugh 1981). These principles of system dynamics can be applied to decision processes to develop their underlying structure (Forrester 1968, Goodman 1974, Randers 1980, Sterman 1989).

At their highest level, systems can be described as being open-loop or closed-loop (Forrester 1968). Forrester identifies open systems as being characterized by current performance is not influenced by past behavior; open-loop systems do not observe, and therefore react, to their own actions. Closed-loop systems, on the other hand, are characterized by the feedback from past performance influencing current actions. Decision processes are

closed-loop systems as they are imbedded in a feedback loop; the decision, based on the available information of the state or condition of the system, controls an action influencing the system condition, which generates new information, which is used to modify the next decision (Forrester 1968; p.4-4).

Interconnecting feedback loops are the basic structural elements in systems which generate dynamic behavior (Forrester 1968, Goodman 1974). "Feedback loops are a closed path connecting in sequence a decision that controls action, the level of the system, and information about the level (or condition) of the system, the latter returning to the decision-making point" (Forrester 1968; p.1-7). However, at a lower level of hierarchy, feedback loops contain a substructure composed of two types of variables — levels and rates (Forrester 1968). The level (or state) variables describe the condition of the system at any particular time while the rate variables tell how fast the levels are changing (Forrester 1968).

To illustrate these points, consider the decision process of filling a glass from a beer tap. When we are thirsty and the glass is empty, the decision is to open the tap fully. As the level of beer in the glass approaches the top, we decide to gradually close down the tap, reducing the rate at which beer enters the glass so that the tap is closed when the glass is full and no beer is wasted.

Causal-loop Diagrams

Causal-loop diagrams identify the principal feedback loops in a system without distinguishing between the nature, i.e. level or rate, of the interconnecting variables (Goodman 1974). Goodman (1974) outlines the steps of developing a causal-loop diagram as follows:

1. establish the pairwise relationships of relevant variables;
2. ascertain the polarity of the causal pairs;

3. fit together the causal pairs into closed loops; and
4. test for loop polarity.

Through this process, the causal-loop diagram allows the analyst to integrate the variables they have developed, explicitly state the inferences they are making and clearly communicate their hypotheses regarding the dynamics associated with the structural relationships of the system.

Pairwise variable relationships are diagrammed with directed arcs. Arcs are used to connect the factors which influence each other; the arrow indicating the direction of influence. Each arc is annotated with an indication of the causal change (polarity) between the two factors.[1] An "S" indicates that the two factors move in the same direction, i.e., all other things being equal, as one variable increases the other variable also increases. An "O" indicates that variables move in opposite directions, i.e., all other things being equal, as one factor increases the other factor decreases. These pairwise arcs can then be connected to form feedback loops.

There are two basic types of feedback loops, reinforcing (positive) and balancing (negative) feedback loops which are used to explain the dynamics of complex situations (Forrester 1968, Goodman 1974, Randers 1980). Reinforcing loops promote movement, either growth or decay, by compounding the change in one direction. Balancing loops resist change in one direction and try to bring a system back to a specified goal or equilibrium state. These two simple structures can be combined in an large variety of ways into casual loop diagrams which can be used describe complex systems.

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[1]Goodman (1974) uses '+' and '-' to indicate positive and negative polarity. Senge (1990) and Kim (1992) advocate the use of 'S' and 'O'.

ISD Step by Step Methodology

The development of Inductive System Diagrams starts with identifying the central variables and concludes with mapping their relationship through causal loop diagrams. An modification of a step-by-step process for developing system diagrams developed by Burchill and Kim (Burchill & Kim 1993) is outlined below:

Step 1: Selecting a Variable

The focus of the investigation is established by identifying significant (core) variables (categories) and their symptoms. The initial selection of a variable is decided by its apparent explanatory ability or central importance in the events being studied. (This implies that considerable open coding and comparative analysis has been conducted by the researcher.) This can be done through axial coding – the process of specifying the varieties of conditions and consequences associated with the appearance of phenomenon referenced by the variable (Strauss 1987;64).

Step 2: Identifying Causes and Consequences

After a significant variable is identified, the next step is to identify other variables closely related to it. The data are analyzed to identify key factors which appear to drive or be driven by the selected variable. This can be accomplished by selective coding, wherein all other subordinate variables and their dimensions become systematically linked to the selected variable. (Strauss 1987)

Step 3: Describe Factor Relationships

After key factors associated with a variable have been identified, their interactions are diagrammed as causal-loop diagrams. The pairwise directed arcs developed during axial and selective coding are integrated into a closed

system. There are usually many variables to explore and it doesn't matter which one is selected first assuming all will be investigated.

Step 4: Check Diagram Consistency

The diagrams should be compared to the collected data to ensure they are grounded in the available facts. Often early diagrams contain links which are not supported by the presented evidence. If upon review, the researcher is confident the loop reflects the system dynamics, additional theoretical sampling or coding is necessary to ensure the theory remains "grounded" in the available data. Additionally, the diagrams should be investigated for "leaps of logic", i.e.. can the diagram describe the patterns of events without explanation. Finally, the diagram is reviewed to ensure factor labels are at the same level of abstraction (Hayakawa 1990). For example, "*Design Constraint Tradeoff*" and "*Performance Comparison*" would be at the same level of abstraction while the abstracted category, "*Systematic Analysis*" would be at a higher level of abstraction.

Step 5: Integrating Causal-loop Diagrams into an Inductive System Diagram

After all significant variables have been diagrammed, the individual causal-loop diagrams are combined to articulate the underlying structure or theory. A central theme is developed using a clearly dominant (core) variable or by linking variables which are common to multiple causal-loop diagrams. Remaining causal-loop diagrams are incorporated into the central theme. Variables may be combined and re-labeled at a higher level of abstraction (Hayakawa 1990). Additionally, low impact loops are eliminated to simplify the diagram. This integrated ISD is validated for logic flow, abstraction levels and consistency with the data.

Product Development Study Example:

An example of the use of ISD in the development of a substantive theory for product development activities follows. The specific coding and analysis examples come from teams using the Concept Engineering method. All field notes were exhaustively coded and analyzed (an average of three hours of off-site effort for every hour of recorded notes) by the author and/or a research assistant. Additionally, much of the coding and analysis was reviewed by colleagues in a Field Research Methods Seminar.

One team went from kick-off to product requirement determination in less than two months and on to final product concept selection in only two more months – considerably faster than historical performance. As a result, Development Time was selected for focused investigation (theoretical sampling/axial coding). Examples of relevant quotes from field notes (*italics*) are provided to illustrate the ISD process.

"(On the previous project) This process would have provided a clearer vision[1], a straighter path to the end result[2]. I see the process saving time[3] by eliminating missteps[4]." - Engineering Development Manager

Coding this statement for variable development might create categories for: 1) Design Vision Clarity, 2) Straighter Path, 3) Development Time, and 4) Missteps. Straighter Path and Missteps are conceptually similar and at a higher level of abstraction could both be dimensions of the category Misdirected Effort. These variables can be diagrammed as follows:

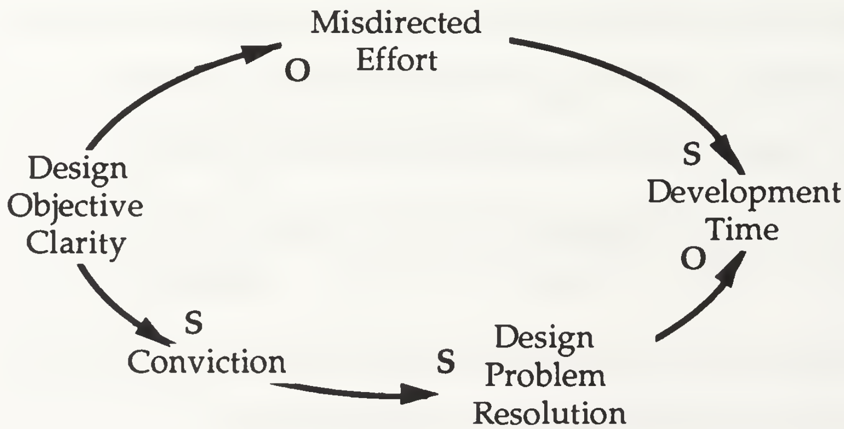
$$\text{Design Vision Clarity} \xrightarrow[\text{O}]{} \text{Misdirected Effort} \xrightarrow[\text{S}]{} \text{Development Time}$$

This diagram indicates that as Design Vision Clarity increases Misdirected Effort decreases causing Development Time to also decrease.

The constant comparison method employed in a Grounded Theory approach requires that events be compared to other incidents in the same category. Accordingly, the following incident, from the same team, which relates to Development Time was compared to the instance above.

"Someone that has buy-in[1] understands the how and why and can explain to other people horizontally or vertically[2]. Along with buy-in is a belief or passion[3]. I think that where there is passion there is ownership and those two combined[4]; when they exist in the same group of people and the team encounters problems they don't last[5]. The team fixes it and moves on[6]." - *Marketing Product Manager*

Coding this statement for variable development might create categories for: 1) Buy-In, 2) Design Objective Understanding, 3) Passion, 4) Ownership, 5) Design Problem Resolution and 6) Development Progress. To simplify coding, Buy-In, Passion, and Ownership can be combined into an abstracted category Conviction. Additionally, Design Objective Understanding is conceptually similar to the variable Design Vision Clarity in the diagram above and is abstracted into the variable Design Objective Clarity. Development Progress is conceptually similar to the variable Development Time; Development Time will continue to be used as it is less ambiguous then Development Progress. The resulting diagram, integrated with the previous diagram, is shown below:



This diagram adds the conditions that Development Time decreases as Design Problem Resolution increases which in turn is driven by Conviction through Design Objective Clarity. The integrated diagram enhances the ability to compare future instances of Development Time with the accumulated knowledge by clearly and concisely displaying the current state of accumulated evidence and inferences.

In comparing instances of Development Time from a second team at another company, using the Concept Engineering approach, an important difference was identified. This difference is exemplified by the following quotes:

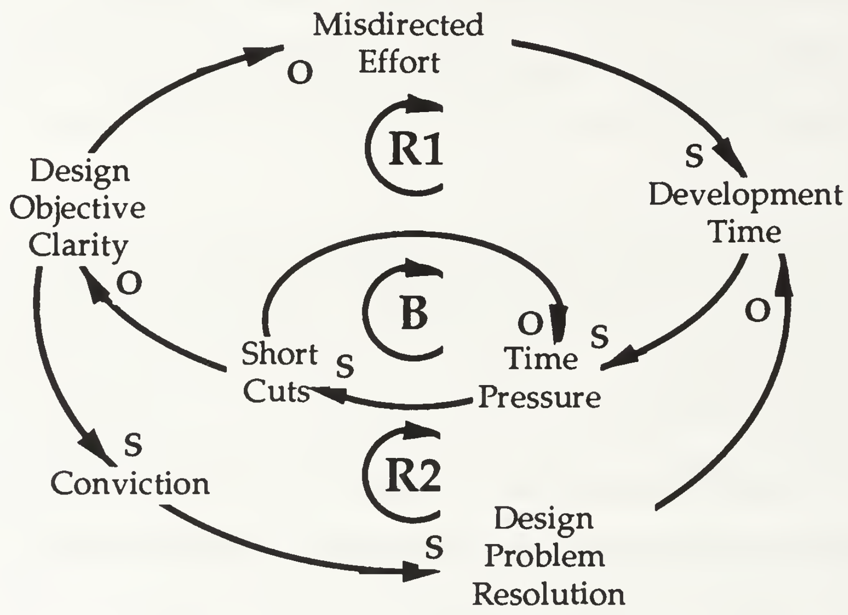
"Also, since we spent a lot of time with the requirement labels yesterday, perhaps we could shortcut a bit on the time without discussion and talk a little sooner." Process Facilitator

"We should generate (requirement metrics) in pairs, then bring the result to a vote. Why not skip the voting step in pairs and vote as a group." Team Leader

From these quotes a new category, Short-Cuts, can be derived. The second team, as a result of several disruptions in their project, planned to complete seven (of fifteen) steps of the Concept Engineering process in one week. Prior efforts, including the first team addressed above, allocated two to three weeks for these same activities. This caused the second team significant, self-imposed, time pressure. Time Pressure was also identified as a relevant variable relating to Development Time. A possible consequence of taking Short-Cuts can best be seen in one of the final comments during the second teams reflection period late Friday afternoon.

"Surprises me, that after all the discussion this week, some people don't know what others are talking about. I should say everyone doesn't know what the others are talking about." Development Engineer

Adding the new categories, Short-Cuts and Time Pressure, to the diagram of accumulated knowledge above, results in the following diagram:



This causal-loop diagram shows two reinforcing loops (R1 and R2) and one balancing loop (B). The reinforcing loops imply that increases in Design Objective Clarity can decrease Development Time and subsequently Time Pressure as a result of less Misdirected Effort and/or as a result of increased Conviction and Design Problem Resolution. The reduction in Time Pressure leads to decreased Short Cuts which increases Design Objective Clarity. The balancing loop implies that as Time Pressure increases Short Cuts also increase, thereby decreasing Time Pressure. However, Short Cuts also decrease Design Objective Clarity causing an increase in Misdirected Effort and a decrease in Conviction. This diagram can be continually validated as

additional instances of Development Time come to light; new variables will be added or relationships modified as dictated by the data. Eventually, modifications become fewer and a theory about Development Time, grounded in the data, can be clearly and concisely stated.

Inductive System Diagram Reliability Assessment

In the fall of 1992, seven Sloan School graduate students were presented with the Inductive System Diagram instructions and example presented above and extracts from my field notes, figure 3.2. The students ranged from Ph.D. candidates in System Dynamics to M.S. candidates with no prior exposure to System Dynamics. Each student independently prepared an Inductive System Diagram. In addition to providing final diagrams, many of the students also provided annotated transcripts, preliminary diagrams and the amount of time spent on the exercise. (Many of the individuals who indicated more time developed diagrams with fewer variables. I conclude from this, that some participants put more effort into the abstraction and simplification procedure described in step 5 of the Inductive System Diagram process. Therefore, a diagram with fewer variables and relationships may reflect a higher level of synthesis.)

The segments below come from an interview conducted with a member of a development team which was in the final stages of Concept Engineering. This team began in June 1992, spending an average of two days per week working together. This interview was conducted in September 1992. The person being interviewed is the Engineering Manager for the business unit.

¿You've mentioned this was a process which was pretty well defined and handed to you, what is it about process that makes it appealing?

Processes are nice just to know where you are. You need some sort of understanding to know where you are, where you want to be, are you heading in the right direction, sort of a navigational tool. .....

¿Continue staying with process for a moment, what else is there?

I think I still believe it is a good process, I see some potential benefits. It is going well, it is fun. I am almost tempted to say I am looking forward to it. It is one of the first times one of the TQM, activities has been enjoyable and fruitful. I haven't seen anything that indicates it is any less a potential solution to our problem. Although I have not had much contact with recent design projects, I don't believe we have ever gone out to customers without defining the product first. We haven't ever had so much discussion between engineers and marketing. We used to be sending a memo around, Engineering sent one, Marketing sent one, I don't think they read each others. I think all of this discussion ...

¿Can you describe what about the process makes you willing to spend so much time?

I can say it the other way around, the negative, if I didn't think it was helpful I wouldn't spend so much time on it.

¿What is the Impact of interaction between marketing and engineering?

I hope it is gonna makes things go a whole lot smoother down the road. Once we do decide what we are going to do there shouldn't be any surprises. Having spent all this time with the marketing guy, those decisions will be made pretty quick . We have covered so much it will be hard to think we haven't thought about something. This is a social process that probably hadn't existed before. This is surely going to break down some barriers. They are both going to know where the definitions came from and that will make the resolution of conflict a lot easier and there will also be a lot of day to day contact between them. Traditionally the designer, in the 6 to 9 months that the designer does his thing, normally doesn't talk to the marketing guy. When he is done he just gives it to them and they say "hey, where is this or that"

¿Why wont there be surprises?

Communication issue. I hope the marketing and design guys will communicate after getting to know each other so well in this process. We have covered so many issues if something comes up they will say ya we covered that and will remember. Once we are done with this almost exhaustive idea generation. When we decide what to do we will understand a whole lot better what it is we are trying to do. It has been just recently that we have had a design document. Marketer writes the front page and the designer writes the back page and they don't read each others work. They are doing this together and will know where the roots are.

¿What is the impact of knowing the roots?

They are going to know how we got to where we are in the product definition. I would hope that it will keep us from going back and going off in a tangent. Once we get to that definition there should not be a whole lot of waffling, we should feel pretty comfortable about it. I don't think there will be a whole lot of questioning. Other aspect if designers do come across something we didn't expect they will recall we talked about that and will have a basis for discussing this with the marketing guys. It should be a pretty quick way for reevaluating the definition. It is always nice too know where you have come through. need to know where you want to go but need to know where you've been and where you are.

¿What is the Impact of not waffling?

the design should go a lot quicker. Designers wont get off on a tangent spending a week or two chasing something they think is neat, they will be more efficient. They will know what to solve and what not to solve.

figure 3.2

Reliability Assessment Method

Each diagram was quickly reviewed for conformance with basic system dynamic modeling requirements. One diagram was rejected from further consideration as the author (someone with no system dynamics exposure) duplicated the same variable in multiple loops rather than connecting the loops through a single expression of the variable. The remaining six diagrams were reviewed to assess: the degree to which the diagrams reflect similar variables, the degree to which variables are connected in similar sequence; and the degree to which the overall structure is similar.

Variable Comparison

To assess the degree to which the diagrams reflected similar variables, each variable was written on a separate slip of paper. Those variables which expressed a similar concept were grouped together, figure 3.3. If a grouping contained multiple variable names from the same diagram, the original diagram was reviewed to ensure consolidation of variables was consistent with the original drawing. For example, in diagram #3, the variables: Speediness of Decisions, Development Time, Effectiveness, and Development Progress could be consolidated under the concept of Product Definition Time without changing the structure of the original causal loop diagram. However, in diagram #2, combining the variables, Time Spent in Process and Perceived Progress in Project under the Product Definition Time concept would have been inconsistent as the author of Diagram #2 linked the variable Time Spent in Process to the interview statement: "...if I didn't think it was helpful I wouldn't spend so much time on it." After ensuring consistency, the group label was selected as the best exemplar of the concept in the grouping. Variables from each diagram which were not initially placed in a group were then reviewed to see if they could be added to an existing group, without changing diagram structure, to simplify analysis.

Exemplar	Diagram 1	Diagram 2*	Diagram 3	Diagram 4	Diagram 5	Diagram 6
product definition time	•project definition time •time pressure	•perceived progress in project	•efficiency of process	•design cycle time	•expediency of developing objective •process efficiency	•product definition speed
level of cross functional communca -tion	•Socialization between Mrkt & Engineering •level of discussion between Mrkt & Eng.	•communica-tion between Eng & Mrkt	•day-to-day contact & interaction between Mrk & Eng. •ground covered in interactions	•level of cross functional communca-tion	•communica-tion •functional interaction	•Eng/Mrkt interaction •communica-tion barriers
design clarity	•Design Quality •number of design issues missed	•clarity of design effort goal •clarity of direction	•understandin g of definitions & "what trying to do"	•product definition •understandin g customer requirements	•design clarity •product definition	•throughness of product definition
Use of Concept Enginering	•Use of CE	•willingness to follow process	•CE •process definition	•use of the process	•process definition	•use of new process
Support for process	•perception of project success •level of managerial happiness	•perceived potential benefit of process •time spent in process	•support for process •enjoyment of process	•realization of process benefits		•belief in potential •process desirablity •fun
Missteps	•time spent on tangential issues	•effectiveness of process	•waffeling	•no. of adjust. to meet unforeseen requirements		•unanticipated problems
Ease of conflict resolution	•time spent resolving conflicts •conflicts to be resolved	•ease of decision making	•ease of conflict resolution •conflict •barriers btwn Mrkt & Eng			•ease of problem resolution
shared understand -ing	•level of concensus on project definition	•ability to reconstruct discussions	•clarity of process or "understand roots/history •basis for discuss. btwn Mrkt & Eng.			•joint understanding
Misc.			•understandin g of progress, postition in process	•sense of purpose and direction		•status knowledge

Figure 3.3

* The author or Diagram 2 indicated that they wrote all variable names in a positive direction, i.e. the *in-vivo* codes of "missdirected effort" and "wasted effort" were abstracted into the category "effectiveness of effort"

Directed Arc Comparison

To assess the degree to which the diagrams reflected similar pairwise associations , each diagram was first redrawn annotating which variables in the original diagram would be consolidated under the exemplar **(bold)** identified above in lieu of the original variable labels, e.g. figure 3.4.

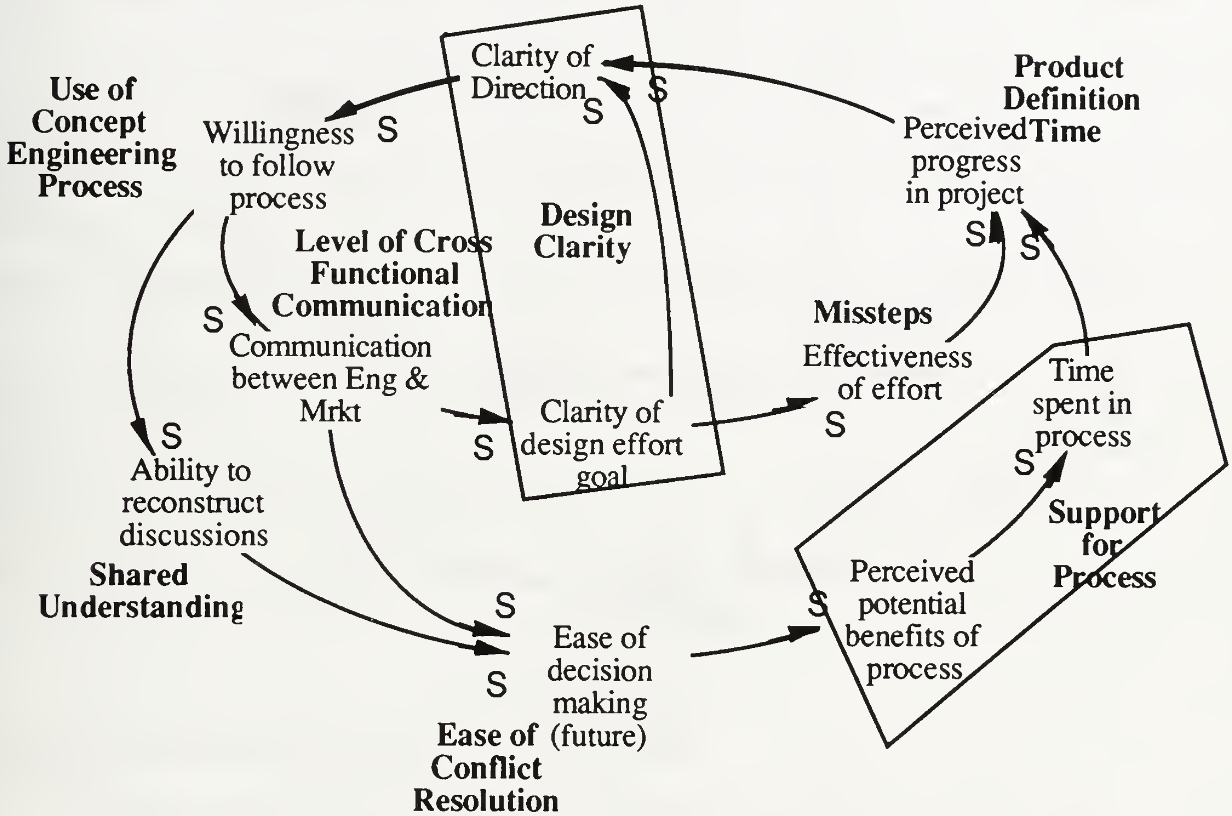


Figure 3.4

Each diagram was subsequently redrawn using only the common variable names, e.g., figure 3.5. In redrawing the original diagram with new variable names the sign of the arc connecting two variables may need to be changed. For example, the author of diagram 2 explicitly chose to write all variable names in a positive orientation, i.e., the references to "misdirected effort" and

"wasted effort" in the text were abstracted into the variable "Effectiveness of Effort". However, the exemplar chosen for this category was Missteps. As a result, the relationship between Design Clarity and Effectiveness of Effort is reversed from that between Design Clarity and Missteps. Appendix B shows the analysis of all diagrams.

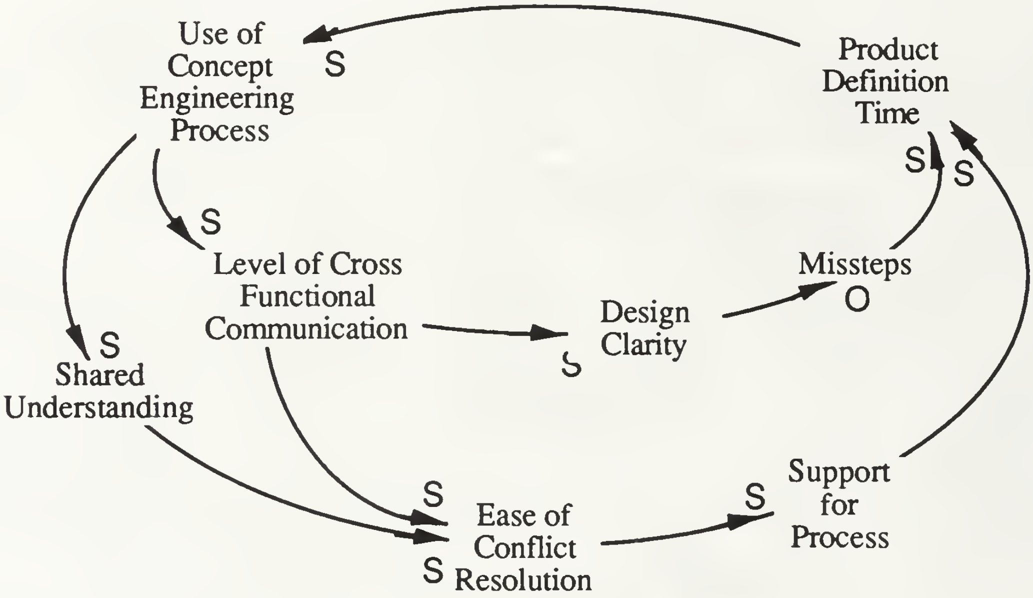


Figure 3.5

Using the redrawn diagrams, with common variable names, each pairwise directed arc connecting two variables was reviewed and the relationship annotated in figure 3.6. A two digit code was utilized for audit purposes; the first digit represents the directional relationship and the second digit represents the source diagram number.

From/To	Product Definitio n Time	Cross Function Commin.	Design Clarity	Use of C. E.	Support for Process	Missteps	Ease of Conflict Resolution	Shared Under-standing
Product Definition Time				O2	**O1,O3, O4,O6**			
Cross Functional Commun.	O5		**S1,S2,S3, S4,S6**				S2,S3	S1,S6
Design Clarity	O5				S1	**O2,O3, O4,O6**	S1	S3
Use of Concept Engineer.	O4,O5	**S1,S2,S3, S4,S5,S6**	S3,S5					S2,S3
Support For Process	S2			**S1,S3,S4, S6**				
Missteps	**S1,S2,S3, S4**				O6			
Ease of Conflict Resolution	O1,O3, O6				S1,S2			
Shared Under-standing			S3			O1,O3	S1,S2,S6	

Figure 3.6

Reliability Assessment Results

A review of figure 3.3 shows all six diagrams reference the following variables: Product Definition Time, Level of Cross Functional Communication, Design Clarity, and Use of Concept Engineering. Additionally, all diagrams except diagram 5 also referenced the variables Support for Process and Missteps. Four diagrams also referenced the variables Ease of Conflict Resolution and Shared Understanding. Unfortunately, due to the varying amounts of time spent in developing the diagrams and the differences in modeling experience, I am unable to conclude if the differences in variable inclusion represent failures on the part of the authors to identify

the concepts or are the result of more effort at abstraction and simplification. However, a review of figure 3.6 indicates that all variables which were connected by more than one author showed a consistent relationship.

Stepping back from the detailed level of analysis to review the basic structures identified by the authors also shows a high degree of consistency. All six authors show a direct relationship from Use of Concept Engineering to Level of Cross Functional Communication. Five of the six authors show a direct relationship from Level of Cross Functional Communication to Design Clarity and the sixth author shows an inverse relationship to Product Definition Time. Furthermore, four of the remaining five authors map a inverse relationship from Design Clarity to Product Definition Time usually via the intervening variable Missteps. All five authors who show a relationship from Product Definition Time indicate it has an inverse relationship either directly to the Use of Concept Engineering (1 diagram) or indirectly through the variable Support for Process (4 diagrams). In summary, all participants in the study identified the same basic structure, figure 3.7.

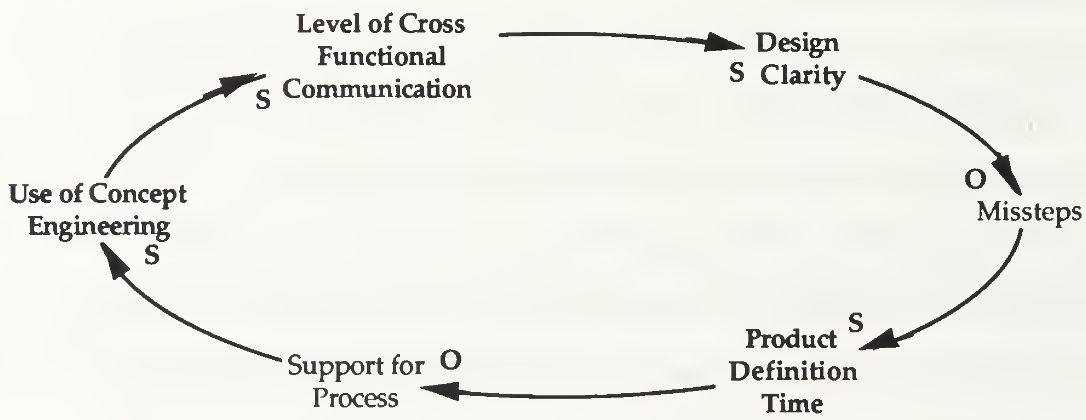


Figure 3.7

Increased Use of Concept Engineering causes increased Levels of Cross Functional Communication which results in increased Design Clarity which leads (via reduced Missteps) to a reduction in Product Definition Time which in turns leads to an increase (via Support for Process) in the Use of Concept Engineering. Furthermore, it should be noted that each variable generated from the data can be operationalized and the predicted cause and effect relationships tested.

The results of this preliminary assessment of Inductive System Diagrams indicates that they appear to be reliable with respect to variable indentification and integration. However, a more complete test, involving more subjects and evaluators is required before a more definitive statement of reliability can be made.

Causal-loop Diagram Limitations

Causal-loop diagrams do not show the level and rate substructure of the system (Goodman 1974, Morecroft 1982, Richardson 1986). In cases involving rate-to-level pairwise directed arcs, the traditional definitions of positive and negative polarity fail because accumulation effects are lost (Richardson 1986). In the filling of the beer glass example used previously in this chapter, the link from the rate of beer flow to the level of beer in the glass fails the traditional definition: here a decrease in the rate of flow from the tap will not produce a decrease in the level of beer in the glass (Richardson 1986; p.160). As a result, accurate prediction of system behavior is difficult using only causal-loop diagrams and more detailed flow diagrams are required before developing simulation models (Goodman 1974, Morecroft 1982, Richardson 1986).

Wolstenholme (1982; p.547) makes a clear distinction between the system description (qualitative) analysis aspects of system dynamics and the simulation modeling (quantitative) techniques and states: "a good system diagram can formalize and communicate a modeler's mental image and hence understanding of a given situation in a way that the written language cannot." Coyle (1983; p.885) states that the difficult part of the operations research discipline is to clearly describe the interrelationships of the system under investigation and that system diagrams require "not much more than patience and persistence to apply ... in reaching a good first approximation to an adequate breadth of view in considering a complex problem." Goodman (1974) concludes that while causal-loop diagrams are insufficient for constructing simulation models they are useful for model conceptualization by organizing principal components and feedback loops.

Conclusion

Inductive System Diagrams have been introduced as a diagram-based method for systematic field-based hypothesis development and integration. Inductive System Diagrams build on the strengths of accepted coding practices for variable development. They can be used to integrate variable relationships and are easily modifiable as additional information becomes available. As a result, they facilitate the ability of researchers to use the constant comparative method of analysis, an accepted approach for theory generation. The Inductive System Diagram method was found to have reliability in a small scale experiment involving experienced and novice dynamic model builders. Additionally, they allow for theory validity testing against the criteria of: verifiable data, explicit inferences and disconfirmable predictions.

Chapter 4: Time to Market Dynamics

The expression "Time to Market" is composed of two distinct components, time and market.[1] In this comparative study, a fundamental difference was observed in the product concept development teams depending on whether they focused on TIME or MARKET in the expression Time to Market. After more than a year and a half of field observations, interviews, and analysis, key variables associated with the product concept development decision process and Time to Market dynamics have been identified using the inductive system diagram process, described in the previous chapter. In this chapter, I present an investigation of the causes, consequences and constraints associated with a focus on TIME or MARKET in the product concept development decision process.

TIME to Market Orientation

Decreased TIME to market has been identified as a key ingredient in successful new product development (Mansfield 1988, Takeuchi & Nonaka 1986, Gupta & Wilemon 1990). There are significant market share benefits to early market entrants (Urban et al. 1986) and considerable penalties for being late to market. For example, McKinsey and Company claims shipping a product six months late can reduce life cycle profits by one third in high growth, short life cycle markets (Reinertsen 1983). Additionally, competitive pressures are reducing product life cycles, further increasing the pressure to reduce product development time (Mansfield 1988, Schmenner 1988, von Braun 1990).

Gold (1987) suggests several strategies to accelerate product and process development. These can be categorized as increasing reliance on external sources of innovation, increasing reliance on internal development of innovation, and

[1]David Walden of BBN Inc. first pointed out this important distinction to me.

increasing reliance on innovative management approaches. Millson, Raj and Wilemon (1992) outline a general framework for reducing development cycle time that consists of simplification, delay elimination, step elimination, operation speedup and parallel processing. Mansfield (1988) shows that innovation time can be reduced by increasing innovation cost. Reinertsen (1983) states that in both high and low growth markets, over-running development costs 50% to meet schedule had only a 4% impact on life cycle profit before tax. Bower and Hout (1988) state that fast cycle capability is a management paradigm which shapes an organization's systems and attitudes around the simple concept that time is money.

Based on the observations and analysis of my field research and supported by the above discussion, I propose the following proposition:

P1: A TIME to market orientation increases pressure for progress.

Time to MARKET Orientation

Considerable research on new product development success highlights the central importance of understanding user needs, i.e., the market (see for example: Rothwell et al. 1974, Cooper & Kleinschmidt 1986, Pavia 1991). Houston (1986) states that customer focus, profits and organizational integration are frequently associated with the marketing concept and have become synonymous with having a customer orientation. Shapiro (1988) describes the characteristics of the market driven company to include widespread dissemination of important buying influence information, interfunctional decision making, and committed coordinated decisions. Narver and Slater (1990) state that marketing orientation consists of three behavioral components: customer orientation, competitor orientation, and interfunctional coordination. Kohli and Jaworski (1990) in an extensive review of the literature found three core themes related to market orientation: customer focus, coordinated

marketing and profitability. However, the results of their 62 field interviews, conducted with a diverse cross section of managers, found that managers felt profitability was a consequence not a condition of market orientation.

Based on the observations and analysis of my field research and supported by the above discussion, I propose the following proposition:

P2: A time to MARKET orientation increases customer oriented bias and functional integration.

Comparison of Product Concept Development Teams

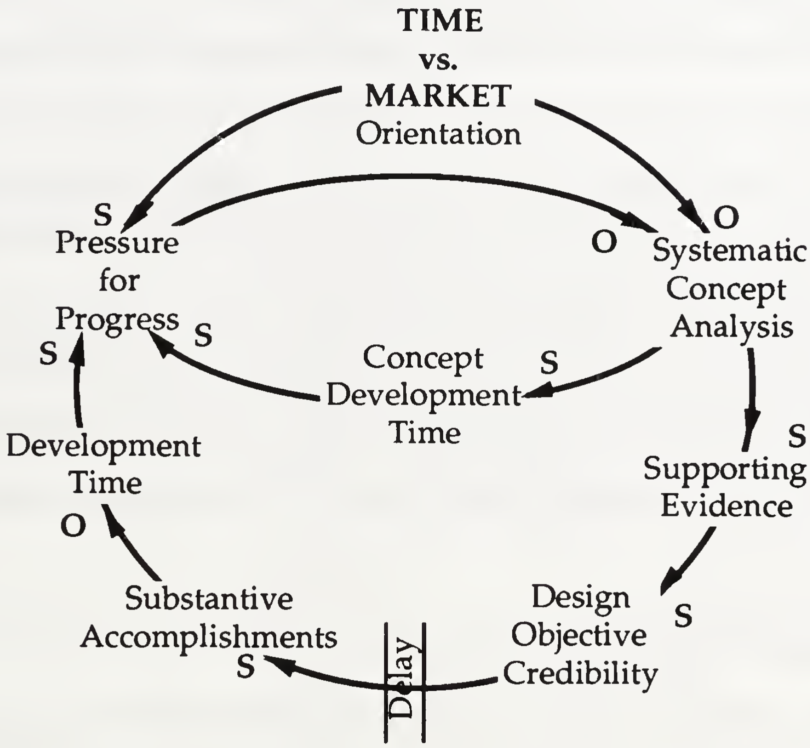
A TIME to market team is one which attempts to specify the design objectives in an accelerated period of time. The team is under a great deal of pressure for progress and displays a willingness to make decisions with recognized data deficiencies in order to meet the (usually aggressive) development schedule. Participants orient their analysis of the issues to support their, often preconceived, perspective of the product concept. In the development team meetings, partisan behavior, in which individuals stake out positions and vigorously defend them, dominates. The engineers discuss product attributes from the perspective of technology opportunities and constraints. Marketers discuss product attributes with respect to market segments and competitors. Although both groups are at the same meeting, they don't participate in the same process: the language used is different, the relative emphasis on product attributes is often different, and individuals can be observed to periodically disengage from the decision process based on discussion subject matter. Product concept decisions are ultimately made, but it is difficult for the entire team to recreate and defend the decision choices to the management review board. When all is said and done, one or more groups lack commitment to the product concept and there is a high expectation that the final product will differ from the initial concept.

A time to MARKET team is one which attempts to develop credible design objectives which reflect a deep appreciation of the customer's requirements. The team is characterized by decision analysis oriented to maximize customer benefit. In development team meetings, every individual participates in all aspects of the decision process. Members frequently put their statements in the context of specific customer encounters to clarify or emphasize their positions. Relevant issues and information regarding design objectives are considered to everyone's satisfaction before the team moves on to subsequent development activities. This cross-functional collaboration to create a common appreciation of the design objectives is apparent when the team presents the product concept to the management review board. All team members display a commitment to the product concept and can credibly trace their decision process when required to justify their choices.

The observed variable relationships are outlined in the table below.

	TIME to market orientation	time to MARKET orientation
Decision Variables		
Pressure for Progress	Higher	Lower
Systematic Concept Analysis		
Prejudiced Perspective	Higher	Lower
Functional Integration	Lower	Higher
Analysis Depth	Lower	Higher
Objective Function		
Supporting Evidence		
Contextual Awareness	Lower	Higher
Process Participation	Lower	Higher
Traceability	Lower	Higher
Design Objective Appreciation		
Requirement Clarity	Lower	Higher
Requirement Credibility	Lower	Higher
Substantive Progress		
Concept Commitment	Lower	Higher
Misdirected Effort	Higher	Lower
Constraints		
Labor-hour Requirement	Higher	Lower

The dynamics of a TIME versus MARKET orientation in the expression Time-to-Market may be easier to understand by representing the data in the table above as a high level inductive system diagram (see Chapter 3).



A relative emphasis on TIME increases Pressure for Progress and reduces the opportunity for Systematic Concept Analysis. This reduction in systematic analysis decreases the labor requirement and consequently the concept development time. However, it also decreases the Supporting Evidence needed to justify concept decision choices. The resulting reduction in Design Objective Appreciation subsequently reduces Substantive Accomplishments as time and resources are spent on tangents and detours in downstream development efforts. The net result is increased Development Time and increased Pressure for Progress.

A MARKET orientation decreases Pressure for Progress, relative to the TIME oriented development teams, and increases Systematic Concept Analysis. The increase in Systematic Concept Analysis increases Supporting Evidence, but also

increases the labor requirement and Concept Development Time. However, the resulting increase in Design Objective Appreciation focuses development efforts thereby increasing Substantive Accomplishments which in turn will decrease Development Time and Pressure for Progress.

The dynamics described above represent a classic "Fixes that Fail" archetype (Senge 1990) in which the unintended consequence of a problem solution over time contributes to the problem it was trying to solve. In this case the emphasis on reducing TIME to market decreases concept development time but inadvertentdly reduces design objective appreciation resulting in waste and rework in downstream development activities increasing total development time. On the other hand, the fundamental solution, an emphasis on MARKET, actually reduces total time by saving the time spent on misdirected downstream development efforts.

Presentation Structure

The presentation of the underlying variables identified in this study follows the order of the left-hand column of the concept decision variable table in the previous section. (This order is also a clockwise rotation around the inductive system diagram presented above.) The decision variables observed in the concept development process include pressure for progress and systematic concept development (prejudiced perspective, functional integration, and analysis depth). The objective function of product concept development activities was observed to be the maximization of supporting evidence (contextual awareness, process participation, and traceability), design objective appreciation (requirement clarity and credibility) and substantive development accomplishments (commitment and misdirected effort). The primary constraint observed was available resources, specifically labor-hours. The table below provides a brief definition of each variable and indicates the page which contains an expanded variable description. The

expanded description includes evidence in the form of representative quotes, a diagram of the inference from the evidence and a propositional statement of the prediction from the inference. Following the expanded definitions, the variables are integrated into an inductive system diagram. A discussion of conclusions, contingencies and rival plausible hypotheses follows the integrated inductive system diagram.

Variable Name	Page	Definition
Pressure for Progress	8	An implicit or explicit force on the development team to proceed rapidly through development activities.
Prejudiced Perspective	10	The formation of an opinion on the product concept without knowing all the facts.
Functional Integration	11	The degree of interaction between functional groups, primarily marketing and engineering.
Analysis Depth	13	The degree of investigative thoroughness associated with concept development decisions.
Contextual Awareness	15	The ability of a development team member to place a requirement statement in the context of the customer's environment.
Process Participation	16	The active involvement of participants in the complete (requirement identification, idea development, and concept selection) process.
Traceability	17	The capability to recreate decision choices with the supporting justification.
Requirement Clarity	18	A product definition in which the vital few requirements and their relative priorities are identified and agreed upon.
Credibility	20	The perceived validity and accuracy of information related to design objectives.
Concept Commitment	21	The level of support the concept has earned from the development team and their managers.
Misdirected Effort	22	Development activities resulting in detours, tangents and missteps relative to the design objectives.
Labor Requirement Gap	23	The difference between required and available labor for concept development.

Decision Variables

In this study the decision variables observed in the concept development problem include pressure for progress and systematic concept development. Pressure for progress was either an explicit or implicit force on the development team to rapidly proceed through development activities. Systematic concept development consists of three components: prejudiced perspective, functional integration, and analysis depth. Prejudiced Perspective indicates the formation of an opinion on the product concept without knowing all the facts; it was observed as biased decision making by internal stakeholders. Functional Integration reflects the degree of interaction between various functional groups in the stages of concept development; cross functional interaction was observed to range from collaborative to partisan. Analysis depth represents the degree of overall thoroughness of analysis associated with the concept development process; investigations were observed to vary from comprehensive to incomplete. It was observed that each of these variables was capable of being influenced by management to a greater or lesser, but always non-trivial, extent.

Pressure for Progress

Several researchers indicate that the pressure for accelerated new product development can cause development organizations to conduct a less than thorough job in order to have the appearance of progress (Van de Ven 1986, Gupta & Wilemon 1990). Contributing to this phenomenon may be the disconnect between product development theory and practice. Bower and Hout (1988) specifically emphasize the requirement that fast cycle companies have development processes which are well defined and understood. They state that in addition to visibility of the process from start to finish, the fast cycle organization understands the interrelationships of the process components and

organizational policies. The strategies outlined by Millson, et al. (1992), e.g. step elimination, delay elimination and parallel processing, all require development process understanding. However, the product concept decision process is not well defined or understood. The observed disconnect between the requirement for process understanding in theory and the lack of process knowledge in practice is consistent with other studies of product development theory and practice which indicate that what the literature recommends and what the actually happens are significantly different (Cooper & Kleinschmidt 1986, Gupta & Wilemon 1990, Mahajan & Wind 1992).

In this study, Pressure for Progress was observed to lead to decision process speedup. When pressured for progress participants were observed to display self-interest oriented behavior based on a prejudiced perspective. Pressure for Progress was also observed to lead to a willingness to make decisions with data deficiencies. Pressure for Progress was observed to dominate other decision variables specifically causing stakeholder orientation and incomplete analysis.

Evidence, inferences and propositions are provided below.

"Some of the features that make the applications engineer job easier, I wouldn't have thought about this if I was under pressure; I wouldn't have put them in my design." - design engineer

$$\begin{array}{c}\text{Pressure}\\ \text{for}\\ \text{Progress}\end{array} \xrightarrow[S]{} \begin{array}{c}\text{Stakeholder}\\ \text{Prejudiced}\\ \text{Perspectives}\end{array}$$

P3: As Pressure for Progress increases Prejudiced Perspectives increase.

"You need to be very quick to get something up on the screen. In the initial stages you don't want to get all hung up on all of the goals" - design engineer

Pressure for Progress $\xrightarrow{S}$ Incomplete Analysis

P4: As Pressure for Progress increases Analysis Depth decreases.

Prejudiced Perspectives

Van de Ven (1986) claims the first, of four, central problems in managing innovation involves the problem of managing human attention; overcoming individuals', and organizations', natural tendency to be focused on and protective of, existing practices. The self-interested behavior of individuals (or groups) in settings which require interdependencies can lead to conflict (Kohli & Jaworski 1990, Ancona & Caldwell 1992). Self-interested behavior and conflict lead to reduced cross-functional integration (Gupta et al. 1986, Souder 1988, Kohli & Jaworski 1990, Ancona & Caldwell 1992).

Dougherty (1992) suggests that viewing the product from the user's perspective can provide a basis for developing a common understanding of the desired innovation. Developing the user's perspective involves more than obtaining the customer's verbalized needs and preferences; it includes analysis of the factors which influence those needs and preferences (Kohli & Jaworski 1990). Placing design engineers in direct contact with customers provides an opportunity for developing this deeper level of understanding (Rothwell et al. 1974, Kohli & Jaworski 1990, Bailetti & Guild 1991).

In this study, analysis was observed to occur from either a customer or stakeholder perspective. Customer oriented perspective is present when the concept development decision process biases innovation efforts towards

customer benefits. Customer orientation was most often evident by the use of numerous, specific, references to customers during all phases of the design objective decision process. In contrast to customer orientation is stakeholder orientation. Stakeholder oriented perspective is evident when the decision process is biased towards satisfying the prejudiced opinions of people in positions of power (on the team or in management) who often dictate product design objectives. In this study, it was observed that Customer Orientation increased Contextual Awareness and Crossfunctional Collaboration.

Evidence, inferences and propositions are provided below.

"Getting oriented to customer needs, in some cases changing biases and getting intimately familiar with customer requirements and environments." - team leader

$$\text{Prejudiced Perspectives} \xrightarrow[\text{O}]{} \text{Contextual Awareness}$$

P5: As Prejudiced Perspectives decrease Contextual Awareness increases.

"If development and marketing hear more of the same stuff from customers it has to build a better working relationship." - team leader

$$\text{Prejudiced Perspectives} \xrightarrow[\text{O}]{} \text{Crossfunctional Collaboration}$$

P6: As Prejudiced Perspectives decrease Functional Integration increases.

Functional Integration

Lawrence & Lorsh (1967; p.11) define integration as the "quality of the state of collaboration that exists among departments that are required to achieve unity of effort by the demands of the environment". Functional integration has been shown to be a key factor in successful innovation (Rothwell et al. 1974, Gupta et al. 1986, Gupta & Wilemon 1988, Pinto & Pinto 1990, Moenaert &

Souder 1990, Dougherty 1992, Song & Parry 1992). Innovation is essentially an information based activity and as a result information transfer is the major integration vehicle (Moenaert & Souder 1990). Communication effectiveness has also been linked with innovation success (Rothwell et al. 1974, Ancona & Caldwell 1992). However, achieving effective communication and integration is difficult; nearly 2/3 of the 289 new product development efforts studied by Souder (1988) experienced some degree of interface disharmony between R&D and marketing.

In this study, all of the companies observed had a practice of assigning multiple functions, marketing and engineering at a minimum, to product concept development teams. However, the degree of interaction among the various functional groups on the development team was observed to range from collaborative to partisanship. Crossfunctional collaboration is the ability of different functional groups to work *together* in the concept development decision process. In collaboration, a synthesis of the perspectives of the functional representatives assigned to the team is incorporated into the concept development decision process. In contrast to crossfunctional collaboration is functional partisanship: the advocation or strong support of one particular perspective. In this study, crossfunctional collaboration led to process participation. Functional Partisanship was observed to lead to incomplete analysis.

Evidence, inference and propositions are provided below.

"If designers do come across something we didn't expect they will recall we talked about that and will have a basis for discussing this with the marketing guys. It should be a pretty quick way for reevaluating the product definition." - engineering manager

Crossfunctional Collaboration $\xrightarrow[S]{}$ Process Participation

P7: As Functional Integration increases Process Participation increases.

"The designer and marketing guy go to the field and get information. Interpretation of the data and how to apply it to a product is left up to the individual and people interpret differently based on their backgrounds" - design engineer

Functional Partisanship $\xrightarrow{S}$ Incomplete Analysis

P8: As Functional Integration decreases Analysis Depth decreases.

Analysis Depth

Several studies indicate that innovation success is significantly impacted by the number of product development process steps completed; the more thorough the job the more likely the success (Cooper & Kleinschmidt 1986, Gupta & Wilemon 1990, Wilson 1990, Mahajan & Wind 1992). Unfortunately, Cooper and Kleinschmidt (1986) found that "up front" new product development activities were more likely to be performed poorly or not at all. Additionally, Moenaert and Souder (1990) indicate that industrial new product development success is related to the effectiveness of information processing. However, Gupta & Wilemon (1990) found 47% of the participants in their study were frustrated by the lack of attention to detail during product development.

In this study, the analysis associated with product concept development was observed to range from comprehensive to incomplete. Comprehensive analysis entails a thorough identification of key design requirements, an extensive development of alternative ideas and a systematic concept selection process. In contrast to comprehensive analysis is incomplete analysis. Incomplete analysis is characterized by decisions with both recognized and unrecognized data deficiencies and resulting premature switching between decision process stages. In this study, it was observed that Comprehensive Analysis leads to traceability whereas Incomplete Analysis does not.

Evidence, inference and propositions are provided below:

Marketing Rep: "Lets move on to the competition comparison sheet; did you get .1%?
Engineering Rep: "No I didn't; but of course I'd be better."
Marketing Rep: "Any idea?"
Engineering Rep: "Totally a guess; maybe 10 instead of 15."
Marketing Rep: "I'll leave it blank."
Observer: Product definition presentation to management one week later listed 10 for this specification.

"When I use 'systematic thinking' in this I think here is what the customer said and here is the requirement which matches what he said." - marketing manager

$$\text{Analysis Depth} \xrightarrow[S]{} \text{Traceability}$$

P9: As Analysis Depth increases Traceability increases.

Objective Function — Supporting Evidence

Supporting Evidence provides participants the ability to justify the decisions made during the *entire* concept development decision process. There were three observed conditions associated with supporting evidence: contextual awareness, process participation and decision traceability. In the time to MARKET teams, references to customer contexts were used to clarify issues throughout the entire concept development decision process. Participation in the decision process allows the design team member to know the background on how the design objective decisions were reached. Evidence provides participants a way to confidently recreate the decision process should/when the need arise in the future.

Contextual Awareness

Moenaert and Souder (1990; p.221) state: "A variable that has been seldom addressed in previous research, and which seems to be essential to the use of information received from other functional fields, concerns the contextuality of the received information. The contextuality of information refers to the degree to which the source has given the receiver the necessary information and references such that the receiver can see the relevance of this information for his/her work on a particular project." They conclude that extrafunctional information, without supporting context, cannot be processed and used.

In this study, Contextual Awareness of the customer's requirements was observed to increase the clarity of the design objective. Contextual awareness is the ability of development team members to place a requirement statement in the context of the customer's environment. Written requirement statements ideally represent a high fidelity translation of the customer's actual needs. However, even in the best processes for capturing the voice of the customer, the written requirement statement lacks the affective qualities of an actual customer interaction and is subject to different interpretations. Placing requirement statements in the context of the customer's use environment clarifies the intent of the requirement statement. In this study, it was observed that stories of real customer experiences, whether obtained specifically in efforts associated with the current project or in other efforts, were used by development team members to clarify written requirement statements.

Evidence, inferences and propositions are provided below.

"The team began a discussion of what a requirement statement meant. Eventually they went back to the interview transcript and rewrote the requirement statement." - observer

$$\begin{array}{c}\text{Contextual}\\\text{Awareness}\end{array} \xrightarrow[S]{\hspace{3em}} \begin{array}{c}\text{Requirement}\\\text{Clarity}\end{array}$$

P10: As Contextual Awareness increases Requirement Clarity increases.

Process Participation

Several studies indicate that interaction between producers and users of market information significantly impacts the credibility and utilization of the information in the innovation process (Deshpande & Zaltman 1982, Deshpande & Zaltman 1984, John & Martin 1984). Gupta and Wilemon (1988) state that credibility has two main components — information credibility and source credibility. Deshpande and Zaltman (1982) conclude that personal interaction increases trust in the source and consequently the content of the research. Additionally, crossfunctional participation in market research increases the effectiveness of information exchange between functions (Deshpande & Zaltman 1984, Kohli & Jaworski 1990). John and Martin (1984) found that the proximity of participants to the marketing planning activities enhanced credibility which they attribute to communication facilitation.

In this study, Process Participation was observed to build design objective credibility. Process participation represents the active involvement of participants in the complete decision process. This implies that individuals participate in requirement identification, idea development *and* concept selection activities. This is contrasted with event participation in which individuals participate in some events and not others, i.e. participation in concept selection but not requirement identification activities. Participation in all stages of the design objective decision process provided team members with a common understanding of the events which led to the concept selection; this increases requirement clarity and credibility.

Evidence, inferences and propositions are provided below.

"They (marketing and engineering) are doing this together and will know where the roots are. They are going to know how we got to where we are in the product definition." - engineering manager

$$\text{Process Participation} \xrightarrow[S]{} \text{Requirement Clarity}$$

P11: As Process Participation increases Requirement Clarity increases.

"There was engineers in the process. It wasn't marketing pukes saying this is what it is. When we got into the room there was built in credibility because the person who is processing the information is witnessing data collection." - marketing manager

$$\text{Process Participation} \xrightarrow[S]{} \text{Credibility}$$

P12: As Process Participation increases Credibility increases.

Traceability

Van de Ven (1986) states that the legitimacy of the decision process is the dominant evaluation criteria used to assess innovative ideas as the ideas themselves can rarely be judged. Deshpande and Zaltman (1982) found that managers were inclined to pay critical attention to research methodology when the findings were surprising. Moenaert and Souder (1990) found that information which was not formally substantiated by convincing evidence was less likely to be used. They also observe that a disadvantage of face-to-face discussions is the absence of hard copy which can be used in the future to justify actions taken.

In this study, Traceability was observed as a highly desirable outcome for justifying the decisions made during the product concept development process. Traceability includes, but is not limited to, documentation of the outcomes of the decision process. Just as importantly, traceability regarding the concept

development decision process itself provides credibility to the identification, development and selection of design objectives. In this study, it was observed that the ability to document the decision process increased the credibility of the design objective decisions.

Evidence, inferences and propositions are provided below.

"I have higher confidence and better ability to sell to executive committee because the process is self-documenting." - marketing manager

$$\text{Traceability} \xrightarrow[\mathbf{S}]{} \text{Credibility}$$

P13: As Traceability increases Credibility increases.

Objective Function — Design Objective Appreciation

Design objective appreciation occurs when the development team has discriminating perception and confidence in a clearly defined set of requirements. Requirement clarity results from understanding the vital few requirements and the relative priorities within this set of requirements. Design activities fundamentally involve making tradeoffs; design objective appreciation facilitates tradeoff optimization. The development team needs to clearly understand the subset of the total universe of requirements which will be emphasized in the product concept to ensure effort is focused effectively. Requirements are assessed for credibility, by the development team, in order for them to have confidence in the relative merit of the tradeoff decisions.

Requirement Clarity

Understanding user needs has long been recognized as a significant factor to new product development success (Rothwell et al. 1974, Cooper & Kleinschmidt 1986). The absence of a clear product definition has been linked to

instability in product and marketing plans (Gupta & Wilemon 1990, Wilson 1990). Gupta and Wilemon (1990) found poor definition of product requirements was the reason most cited for product development delays.

In this study, Requirement Clarity was observed to consist of two components: the identification and agreement on the vital few requirements and their relative priorities. The establishment of the vital few requirements focused development efforts. In all observed projects, the development team attempted to identify a small subset of the total requirements which would differentiate the proposed product from the competition (either internal or external). Knowing the relative importance of these key requirements assists in making development tradeoffs. The relative requirement priorities clarify what to work on and, just as importantly, what not to work on. There was a concerted effort on each observed development team to clearly establish the relative priorities of acknowledged design objectives. The product definition, by focusing on only the vital few requirements, is designed to serve as a road map for the development team, providing direction and flexibility for making tradeoffs while minimizing unproductive effort.

Evidence, inferences and propositions are provided below:

"Documented lists of the most important things to be concerned with ... all too often you put blinders on, getting in a rut, attacking one piece of the problem and let other aspects slide." - design engineer

"The implication of having visibility (of customer requirement priorities) is it tells you what is good enough, where you have to put efforts or where you can compromise, not spend time." - design engineer

$$\text{Requirement Clarity} \xrightarrow[O]{} \text{Misdirected Development Effort}$$

P14: As requirement clarity increases misdirected development effort decreases.

Credibility

John and Martin (1984) define credibility as a composite of six components related to the perceived quality of the marketing plan; these components assess whether the plan is: realistic, accurate, specific, consistent, complete, and valid. Gupta and Wilemon (1988) conclude that in organizations with a high degree of integration between marketing and R&D, R&D personnel perceive marketing information to be: realistic and valid, objective, consistent and complete, useful and appealing. Moenaert and Souder (1990) define credibility as a measure of the degree to which the receiver believes the information to be undistorted and state that the credibility of received information will be a positive function of: validity, accuracy and clarity and a negative function of surprise. Deshpande & Zaltman (1982) focus less on "credibility" per se but rather on the instrumental use of knowledge; it is the knowledge applied to a particular decision. They identify four dimensions of instrumental use: information relevance, information surplus, recommendation implementation and overall satisfaction.

In this study, it was observed that credible design objectives obtain commitment. Requirement statements were tested, either formally or informally, for credibility. The credibility of the vital few requirement statements reinforces commitment to the design objective. Requirements without credibility are discounted, thereby reducing commitment to the stated design objectives.

Evidence, inferences and propositions are provided below.

"Post program approval then run in automatic; hard work but people already know what to do and want to do it." - engineering manager

$$\text{Credibility} \xrightarrow[S]{} \text{Committment}$$

P15: As credibility increases commitment increases.

Objective Function — Substantive Development Accomplishment

Substantive development accomplishments are development actions which lead directly to real progress towards realizing the design objectives. Substantive development accomplishment, in the context of the concept development decision process, has two dimensions: concept commitment, and focused effort. Concept commitment represents the ability of a product concept to garner enough enthusiasm and support from the development team that it does not change during subsequent development activities. Focused effort describes a development process which is direct compared to one filled with detours.

Concept Commitment

Several authors claim commitment is a result of participation in the formulation stage of a project (Gupta, Raj & Wilemon 1986, Shapiro 1988, Moenaert & Souder 1990, Gupta & Wilemon 1990, Bailetti & Guild 1991). Gupta & Wilemon (1990) indicate that a lack of commitment is related to changes in product definition and low management support.

In this study it was observed that design objective appreciation led to concept commitment which in turn led to reduced misdirected development effort. Concept commitment represents the level of support the product concept has earned from both the development team and their managers. Committed individuals ensure the necessary work get accomplished. Committed managers provide the necessary resources to support the team's efforts. Concepts with commitment don't change during the development process. Changing product concepts often make prior development activities useless creating waste and rework.

Evidence, inferences and propositions are provided below.

"We didn't have confidence, (therefore) we didn't want to tinker because it would be wasted effort." - engineering manager

Concept Commitment $\xrightarrow[O]{}$ Misdirected Effort

P16: As concept commitment increases misdirected effort decreases.

Misdirected Development Effort

As mentioned previously, the absence of a clear product definition has been linked to instability in product and marketing plans (Gupta & Wilemon 1990, Wilson 1990). Instability can manifest itself in significant changes in direction or in "creeping elegance" (Gupta and Wilemon 1990). Wilson (1990) found that product definition instability could lead to more staffing, funding and time.

The System Dynamics literature has investigated the impact of project changes in a variety of development settings, e.g. construction (Homer et al. 199), research and development (Roberts 1964, 1978, Richardson & Pugh 1981), shipbuilding (Cooper 1980, Reichelt & Sterman 1990), and software (Abdel-Hamid & Madnick 1989, 1991), and consistently find project changes directly and indirectly increase development time and costs. Abdel-Hamid and Madnick (1989; p.1427) state: "the rework necessary to correct such software errors obviously diverts the project team's effort from making progress on new project tasks, and thus can have a significant impact on the projects progress rate." They explicitly model the relationship from progress-rate to forecast completion date to schedule pressure. Roberts' discussion of research and development project control indicates that "there is no intrinsically correct measure either of engineering effectiveness or of problems solved or of the task left to be done....the

obvious concrete and measurable variables are often basically unrelated to the amount of effort required to get the job done" (1964; p.169). Roberts indicates (1964, 1978) that one result of this measurement difficulty is a delayed response to events which impact the development schedule.

In this study, it was observed that a reduction in Misdirected Development Effort decreased development time. In addition to tangible time savings, reduced misdirected effort was observed to increase the sense of accomplishment of the team. It is assumed that the time saved through reductions in tangents, detours, missteps, etc. decreases Pressure for Progress and Labor-hour Requirements.

Evidence, inferences and propositions are provided below.

"This process would have provided a clearer vision, a straighter path to the end result...I see the process saving time by eliminating missteps" - design engineer

$$\text{Misdirected Effort} \xrightarrow[S]{} \text{Development Time}$$

P17: A decrease in misdirected effort decreases development time.

P18: A decrease in development time decreases pressure for progress.

P19: A decrease in development time decreases labor-hour requirements.

Constraints — Labor-hours

Constraints are limits placed on decision variables. Although the list of conceivable constraints which can be imposed on the decision variables outlined above is considerable, one, required labor-hours, dominated the observations in this study of product concept development. As the innovation process is primarily informational (Moenaert & Souder 1990) it can be argued that mental capacity (labor) is the critical resource. The Labor-hour requirement gap represents the

difference between required laborhours and available laborhours. When Labor-hour requirements exceed availability the gap is large. In this study, labor availability was fixed by the team size. In every observed development team, the membership remainded the same or was reduced during the roughly six month observation period. The labor requirement can be driven by the project itself or by other projects team members participate in. In this study, it was observed that when a Labor-hour requirement gap exists there is an increase in concept development time. It was also observed that systematic concept development (comprehensive, collaborative, customer oriented analysis) increased the labor requirement.

Evidence, inferences and propositions are provided below.

"This process (CE) is taking a long time; not just a long elapsed time because it is not calendar time. But in terms of people time it is extensive." - marketing manager

$$\text{Analysis Depth} \xrightarrow{S} \text{Labor Requirement Gap}$$

P20: As Analysis Depth increases labor-hour requirements increase.

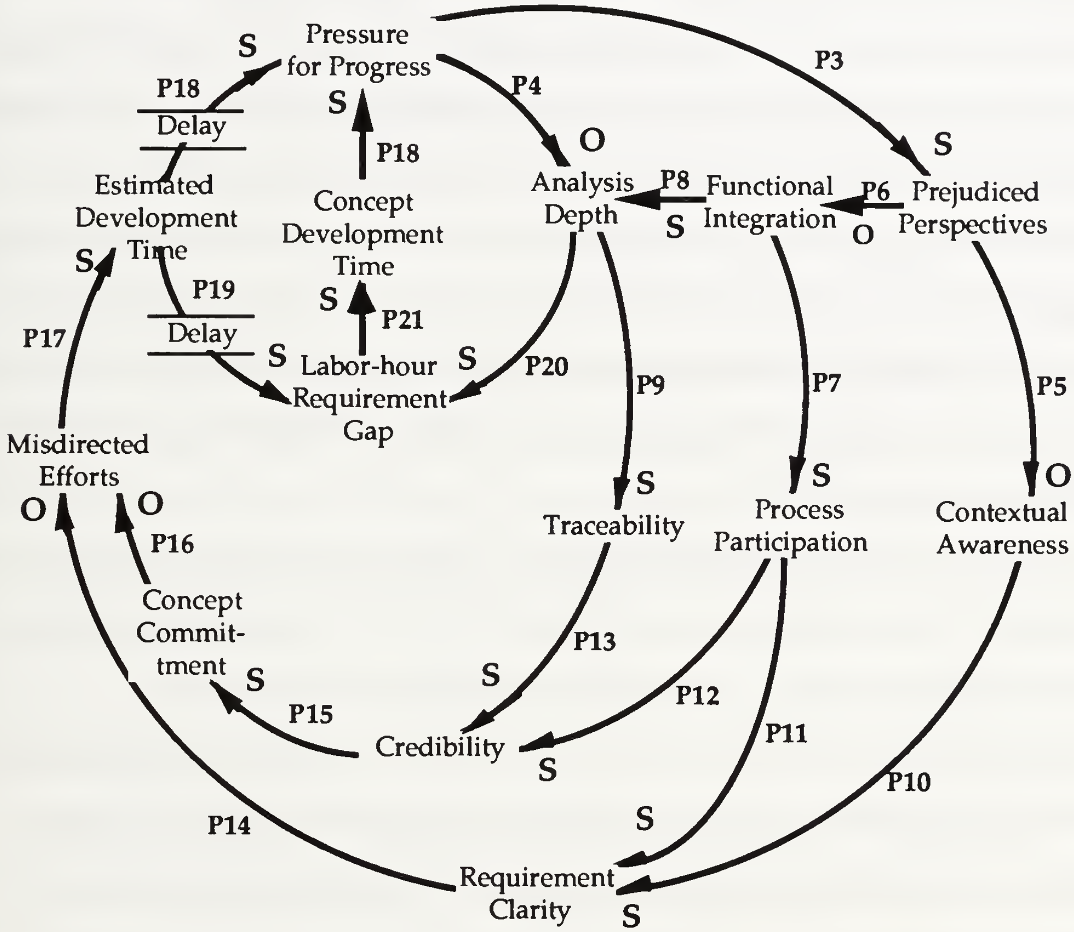
"We have sales quotas to meet, sales growth rates to meet, as a result the managers won't give time to gather and analyze the information (for products not yet defined)." - manager

$$\text{Labor Requirement Gap} \xrightarrow{S} \text{Concept Development Time}$$

P21: As the labor requirement gap increases concept development time increases.

Integration

Combining the relationships identified above into an integrated diagram allows us to better understand the interactions between the variables associated with the product concept development decision. Each arc of the diagram has been annotated with the relevant proposition number.



This TIME vs. MARKET inductive system diagram can describe a vicious or virtuous cycle of product concept development depending on which decision variables are emphasized. A vicious cycle begins when pressure for progress leads to incomplete concept analysis and stakeholder prejudiced perspectives in decision analysis. The resulting decrease in functional integration further degrades analysis depth and reduces participation of all team members in the

concept decision process. The resulting lack of requirement clarity and credibility leads to low concept commitment and misdirected development effort. Ultimately, the waste and rework increases development time further increasing pressure for progress.

The TIME vs. MARKET inductive system diagram can also describe a virtuous cycle in which an increase in customer orientation perspectives lead to an increase in Functional Integration and Contextual Awareness. As a result, a more thorough analysis, grounded in the context of the customer's environment, is conducted with the active participation of all development team members. This common appreciation of the concept decision process and outcomes leads to a higher degree or requirement clarity and credibility. In turn, commitment to the product concept is higher and misdirected development effort is reduced. Ultimately, development time is reduced, thus decreasing pressure for progress and labor requirements.

The dynamics associated with either a TIME or MARKET emphasis in the expression time to market can be explained by the inductive system diagram above. The level of detail displayed in the diagram provides a more comprehensive causal map than currently exists in the literature. Additionally, it identifies the dysfunctional and unintended consequence which results from a TIME to market orientation during the product concept decision process.

Plausible Rival Hypotheses

The inferences and propositions integrated into the TIME vs. MARKET inductive system diagram above are the result of a comparative analysis of product concept development teams. The differences between the observed teams were both minimized and maximized, within the constraints imposed by company access. The full range of behavior observed in this study is accounted

for in this inductive system diagram. However, the actual implementation of the original research design does not preclude the elimination of some plausible rival hypotheses which will be discussed below.

Senior Management Support

Numerous authors describe the important role senior managers play in creating the Market Oriented organization (Shapiro 1988, Kohli & Jaworski 1990, Narver & Slater 1990). Gupta & Wilemon (1986, 1988, 1990) specifically identify senior management support as a necessary ingredient for creating interfunctional integration and cooperation. In this study, it might be argued that those teams using Concept Engineering received, or at least could be perceived as receiving, a higher level of support from their senior managers than the teams which did not use Concept Engineering. The original research design attempted to address this threat by using pairs of teams from the same division each of which received a beneficial treatment. Unfortunately, the actual design implementation precludes elimination of this threat.

Decision Support Process

White, Dittrich and Lang (1980) found that the more structured the interaction during group decision making, the greater the commitment to the group derived solution, as measured by the number of implementation attempts. Concept Engineering, as a complete decision support process (see chapter 1), is a structured decision making process. A plausible rival hypothesis to the TIME to MARKET dynamics presented above relates to the quality of the decision process employed by the MARKET oriented teams.

Janis (1985; p.167), based on studies of errors in strategic decision making, outlines seven major decision process criteria which are influence the quality of individual or group decisions. High quality group decisions:

1) thoroughly canvass a wide range of alternatives;

2) take account of the full range of objectives to be fulfilled;

3) carefully weigh whatever is found out about negative and positive consequences that flow from each alternative;

4) intensively search for new information relevant for alternative evaluation;

5) conscientiously take account of any new information, even when the information does not support the course of action they initially prefer;

6) re-examine the positive and negative consequences of all known alternatives before making a final choice; and

7) make detailed provisions for implementing the chosen policy, with special attention to contingency plans.

Janis (1985) states it is plausible to assume that failure to meet these criteria are symptoms of defective decision making that increase the chances of undesirable outcomes. Further, he states that the *vigilance* pattern of response is more likely than others to lead to decisions that meet the main criteria for sound decision making. The vigilant decision maker "searches painstakingly for relevant information, assimilates information in an unbiased manner, and appraises alternatives carefully before making a choice" (p. 184). From this perspective, vigilant decision makers, who succeeded in satisfying the above criteria for each stage (requirement identification, idea development and concept selection) of the concept decision process, will have more successful outcomes.

The vigilant decision making argument would indicate that comprehensive analysis is a sufficient factor for success in the product concept decision process. Concept Engineering, as a complete decision support process

(see Chapter 1) satisfies Janis' requirements for high quality decisions as indicated in the table below.

Decision Criteria	Concept Engineering
1) Thoroughly canvasses a wide range of policy alternatives.	In Transforming voices into Requirements (Step 4) 200-300 requirement statements are usually developed. In Concept Generation (Stage 4) teams can generate over 300 solution ideas.
2) Takes account of the full range of objectives to be fulfilled.	In Concept Screening (Stage 5) all concepts are screened against the set of key customer requirements.
3) Carefully weighs whatever is found out about negative and positive consequences that flow from each alternative.	In Concept Selection (Step 14) final concepts are screened not only against customer requirements (positive consequences) but also against organizational, environmental and technological constraints (negative consequences).
4) Intensively searches for new information relevant for alternative evaluation.	In Collecting the Voice of the Customer (Step 2) and Developing and Administering Questionnaires (Step 7) active information discovery and collection occurs.
5) Conscientiously takes account of any new information, even when the information does not support the course of action they initially prefer.	Transforming Voices into Requirements (Step 4) requires every customer statement be developed into a customer requirement for possible inclusion and development in the product concept.
6) Re-examine the positive and negative consequences of all known alternatives before making a final choice.	Solution Screening (Step 13) and Concept Selection (Step 14) require all developed concepts to be evaluated in a matrix against customer / environmental requirements.
7) Make detailed provisions for implementing the chosen policy, with special attention to contingency plans.	This activity is not formally part of Concept Engineering. However, detailed design specification activities usually occur subsequent to concept approval.

In this study, those teams which were successful in developing product concepts achieving a high degree of commitment from development team members and managers were also those teams which completed a comprehensive analysis (Concept Engineering) which satisfied the requirements

outlined by Janis. However, one team which used Concept Engineering was not successful in developing concept commitment. This team had a relative emphasis on TIME versus MARKET and was under considerable pressure for progress. Although a relatively complete investigation was conducted not all participants were active in the entire concept decision process, e.g. three members did not conduct customer interviews, two members did not participate in idea generation. As a result, a common appreciation of the design objectives was not obtained and commitment to the product concept was low. This would indicate that the decision process criteria outlined by Janis may be necessary but are not sufficient for success in the product concept development process.

Market Orientation Contingency

When is too much of a good thing not a good thing? Several authors specify contingencies with respect to the effectiveness of market orientation (Houston 1986, Gupta & Wilemon 1986, Souder 1988, Kohli & Jaworski 1990, Moenaert & Souder 1990, Narver & Slater 1990). Souder (1988) created a matrix with customer sophistication on one axis and R&D sophistication on the other axis and prescribes different tactics for the twelve resulting cells. Kohli and Jaworski (1990) propose that when the general economy is weak there is a stronger relationship between market orientation and business performance. Gupta and Wilemon (1986) propose that if a firm values being first in the market with new products it will benefit from higher integration. Kohli and Jaworski (1990) and Moenaert and Souder (1990) propose that market orientation is less valuable in environments with technological uncertainty but more valuable in environments with consumer or competitor uncertainty. Several authors address the issue that the cost of obtaining more information at some point exceeds the

value of the benefit to be derived from knowledge gained. (Houston 1986, Moenaert & Souder 1990, Narver & Slater 1990).

Most of the above contingencies address when more market orientation is beneficial. However, in the case where technological uncertainty reduces the value for market orientation, the basic dynamics outlined in the high level inductive system diagram still appear to provide valuable insight, i.e. pressure for progress will reduce systematic analysis reducing evidence, credibility and substantive accomplishments.

Conclusion

This investigation shows that a relative emphasis on TIME creates an environment where pressure for progress encourages development teams to conduct incomplete analysis oriented to self-interested outcomes during the concept development decision process. The resulting lack of design objective appreciation and commitment by the development team leads to waste and rework in subsequent product development activities. On the other hand, a relative emphasis on MARKET can increase design objective appreciation, credibility and commitment but increases the time required in concept development. These dynamics indicate that increased time spent systematically developing a product concept, which remains stable over the balance of the development process, results in getting a product to market faster. Schmenner (1988) reminds us of the applicability of the fable of the tortoise and the hare to product development acceleration. The tortoise won the race with a diligent, focused effort and the hare, while very fast, had a pattern of stops and starts in his detour-filled route to losing the race.

Chapter 5: Time-to-MARKET Management Diagnosis

The dynamics of TIME versus MARKET orientation activities has important implications for the management of product concept development activities. The emphasis on TIME clearly implies schedule related measurement and monitoring. The measurement and monitoring requirements associated with an emphasis on MARKET in the expression Time to Market is not so clear. This chapter will explore methods[1] managers can use to diagnose concept development activities in a time-to-MARKET oriented environment.

Product Concept Decision Process

The product concept process can be described to follow the general decision process structure outlined by Mintzberg and colleagues (1976) in their study of unstructured decision processes. In the context of concept development, the three general phases of the decision process are: Requirement *Identification*, Idea *Development* and Concept *Selection*. All three phases — identification, development and selection — were observed, to a greater or lesser extent, in each development team in this study.

In the identification stage, both recognition and diagnosis routines were used to clarify and define the requirements which would drive the product concept. In the development phase, search and design routines were employed to generate ideas which constitute potential solutions to requirements. Finally, in the selection stage, screening, evaluation and authorization routines were employed either by the development team, or a management team, to select and authorize a product concept for additional investment. Janis (1985) indicates that

[1] Metrics presented in this chapter are derived from work conducted with the CQM Research Subcommittee on Product Development Metrics (CQM 1992).

the effectiveness with which these individual activities are carried out influences the outcome of the decision process — the product concept which determines 75% of the product's lifecycle costs (NRC 1991).

Janis (1985) outlines seven major decision process criteria which influence the quality of individual or group decisions. The table below identifies where in the product concept decision process these criterion are most relevant.

	Requirement Identification - recognition - diagnosis	**Idea Development** - search - design	**Concept Selection** - screening - evaluation -authorization
1. Canvasses a wide range of alternatives	X	X	
2. Takes account of full range of objectives		X	X
3. Carefully weights pros/cons of alternatives			X
4. Intensively searches for new relevant information	X	X	
5. Conscientiously takes account of new information	X		
6. Re-examines pros/cons prior to making choice			X
7. Make detailed implementation plans			

To identify a comprehensive set of customer requirements an intensive search of market segment information is required and this new information must be incorporated into concept deliberations. To develop an extensive set of potential product concept ideas, deliberate exploration must occur around the set of key customer requirements. Finally, to determine the best product concept requires a systematic comparison of each candidate concept's ability to satisfy key customer and organizational requirements.

This mapping of decision effectiveness criteria onto the product concept decision process identifies high leverage management diagnosis opportunities. Specifically, within each phase (identification, development, selection) of the product concept decision process, the relevant decision criterion are aligned with variables associated with time-to-MARKET orientation. These variables are then operationalized in a manner which is practical for use in diagnosing actual product concept development activities.

Requirement Identification

Mintzberg et al. (1976) observed that the identification phase consists of both recognition and diagnosis activities. They defined diagnosis as "the tapping of existing channels and the opening of new ones to clarify and define the issues" (1976; p.254). Three decision process criteria are proposed to have potential relevance in requirement identification activities: the search for new information, the range of alternative generation, and the conscientious consideration of new information. Based on the research associated with this study, Customer Orientation, Crossfunctional Collaboration, and Credibility are proposed as the variables with the most direct impact on the relevant decision process criteria.

	Intensive search for new information	Range of alternative idea generation	Conscientious consideration of new info.
Customer Orientation	X		
Crossfunctional Collaboration		X	
Credibility			X

Customer Orientation represents a willingness to search beyond traditional organizational perspectives. Customer Orientation results in developing an understanding not only of the stated customer requirements but also of the factors which influence those requirements (Kohli & Jaworski 1990).

Customer Orientation leads to a more thorough investigation of the customer's use environment.

In Crossfunctional Collaboration, different functional groups work together to form a synthesis of their respective perspectives. This joint analysis of the opportunities leverages the strengths of each functional group in the creation of new insight (Shapiro 1988, Gupta & Wilemon 1986). Crossfunctional Collaboration, compared to Partisanship, leads to the development of a wider range of customer requirements.

Credibility is a function of information credibility and source credibility (Gupta & Wilemon 1988). In this study, it was observed that Credibility was a function of Contextual Awareness and Process Participation. Contextual Awareness caused development team members to develop empathy for the customer which increased the (information) credibility of customer requirements. Similarly, Process Participation allowed team members to personally participate in the creation of the new information increasing its (source) credibility and subsequent utilization. Credibility is required for conscientious consideration of new information.

The Customer Visitation Matrix and a Process Participation Matrix can be used by managers to assess the opportunities for developing customer orientation, crossfunctional collaboration, process participation and contextual awareness.

Customer Visitation Matrix

The Customer Visitation Matrix (Burchill et al. 1992) can assess the degree to which the development team is exploring potential market and the opportunities individual team members have to develop contextual awareness.

Across the top of the matrix, list important customer types,[2] e.g., Lead Users, Demanding, Former, Satisfied, etc. Down the side of the matrix list important market segments and the specific companies to be visited during market exploration. In the intersecting cells, write down the name(s) of the development team members who conducted the customer visit. In the hypothetical example below, the development effort focused on only New England and Mid-Atlantic market segments. Additionally, Smith participated in all customer visits while Green only visited retailers and not end-users. Ideally, to develop contextual awareness participants would visit a representative cross section of customer types.

Customer Selection / Vistation	Lead Users	Demanding	Lost	Retailers	Total
New England	Brown & Smith-2	Smith & Jones - 2	Smith & Jones - 1	Green & Smith-2	7
Middle Atlantic	Brown & Smith-2 Smith & Jones-2	Brown & Smith - 2	Smith & Jones-1	Green & Smith-1	8
South Eastern	0	0	0	0	0
Total	6	4	2	3	15

Process Participation Matrix

The Process Participation Matrix can assess the degree to which individual members of the development team participated in activities associated with concept development. Across the top of the matrix place the departments involved in concept development activities. Down the side of the matrix indicate

[2] See Step 1 of the Concept Engineering Manual (Appendix A) for additional description.

the stages and steps associated with concept development. In the intersecting cells, write down the names and hours of the development team members who participated in the various activities. (This process can be automated through the use of appropriate job numbers in the labor accounting system.) In the hypothetical example below, the total time investment is fairly equal in each department. However, the marketing department, Smith in particular, did the majority of data collection and requirement generation, while the engineering department, White, who did not make customer visits, did most of the requirement evaluation. This imbalance in Process Participation and Contextual Awareness could adversely impact Requirement Clarity and Credibility.

Task	Marketing		Engineering		Total	
Data Collection	Person	M.H.	Person	M.H.	Dept.	M.H.
	Smith	29	White	0	Mktg.	40
	Jones	11	Green	7	Eng.	19
		40	Brown	12		59
				19		
Requirement Generation	Person	M.H.	Person	M.H.	Dept.	M.H.
	Smith	42	White	4	Mktg.	52
	Jones	10	Green	12	Eng.	28
		52	Brown	12		80
				28		
Requirement Evaluation	Person	M.H.	Person	M.H.	Dept.	M.H.
	Smith	10	White	48	Mktg.	35
	Jones	25	Green	12	Eng.	72
		35	Brown	12		107
				72		
Total		127		119		246

Idea Development

The Development Phase observed by Mintzberg et al. (1976) consists of both search and design routines. They indicate four different kinds of search behavior: memory, passive, trap and active and two types of design activities that result in either custom-made or modified solutions. Three decision process

criteria are proposed to have relevance in idea development activities: the search for new information, the range of alternative idea generation and accounts for the full range of objectives. Based on research associated with this study, Customer Orientation, Crossfunctional Collaboration, and Requirement Clarity are proposed as the variables with the most impact on the relevant decision criteria.

	Intensive search for new information	Range of alternative idea generation	Accounts for full range of objectives
Customer Orientation	X		
Crossfunctional Collaboration		X	
Requirement Clarity			X

Customer vs. Stakeholder Orientation represents a willingness to search beyond traditional organizational perspectives. Rothwell et al. (1974) conclude it is desirable "whenever possible" for designers to visit customers to study their technical requirements and also the actual operating conditions. Bailetti and Guild (1991; p.91-92) cite three reasons for designers to visit customers: 1) added insight and useful knowledge, 2) acquiring knowledge depth that facilitates technical activities, and 3) increasing designer acceptance of the results. Customer Orientation should produce additional information on technical considerations.

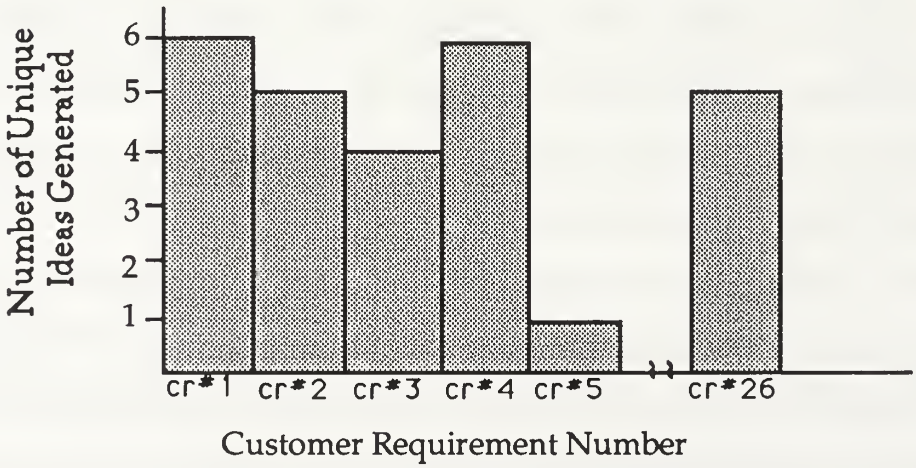
In Crossfunctional Collaboration, different functional groups work together to form a synthesis of their respective perspectives. Different functional groups have different frames of reference and skills which they bring to focus on aspects of the technology-market environment (Van de Ven 1986, Dougherty 1992). These diverse perspectives, if integrated, should generate a wider range of alternatives compared to those generated from partisan perspectives. Requirement Clarity results from understanding the vital few requirements and the relative priorities within this set of requirements. Assessing the degree to which design objectives are met first requires a clear understanding of the design objectives. Requirement Clarity is a necessary

condition for determining if the developed ideas account for the full range of objectives.

The use of the Customer Selection/Visitation Matrix and a Process Participation Matrix, reflecting appropriate stages and steps, can provide some diagnosis capability of the idea development process. Additionally, the Idea Count Chart and the Requirement Utility Matrix can also be used by managers to monitor idea generation activities.

Idea Count Chart

The Idea Count Chart can assess the range of alternative ideas generated. Concept development activities can be decomposed[3] in multiple ways, e.g. by customer requirement, functional requirement, etc. The Idea Count Chart displays the number of ideas generated in each decomposition category. In the example below, a customer requirement decomposition was used and the number of unique ideas associated with each requirement were counted. In this hypothetical example, only one unique idea was generated to address requirement number 5; this may represent an area requiring additional idea generation.



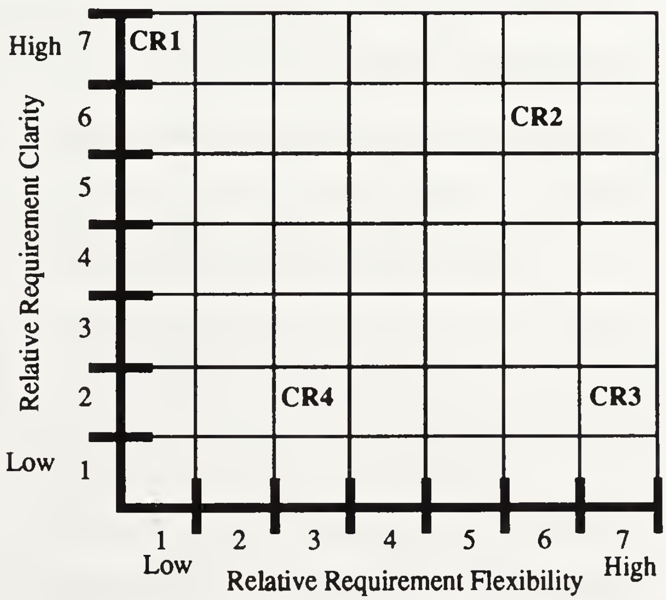
[3] See Step 10 of the Concept Engineering manual (Appendix A) for additional description.

Requirement Utility Matrix

The Requirement Utility Matrix can be used to assess the relative clarity and flexibility of requirement statements. It was observed that the customer's articulation of their need is often ambiguous, does not clearly state the requirement and leaves a great deal of flexibility for designer interpretation. On the other hand, it was observed that the designer's articulation of a customer's need was often a very specific solution; thus greatly restricting designer flexibility. Unfortunately, specifying a requirement as a specific solution, while very clear, restricts the number of generated ideas to the one solution. To develop the matrix, each requirement statement is reviewed and its relative clarity and flexibility are assessed and the requirement is plotted in the appropriate cell. Requirements in the upper left hand corner of the matrix tend to be written as solution statements *not* requirement statements. Ideally, requirement statements have both high clarity and flexibility and would be located in the upper right hand of the matrix.

Example from the Stripping Basket

CR 1: The basket has a velcro fastener.
CR 2: The basket is releasible with one hand
CR 3: The basket is durable.
CR 4: The basket is simple.



Concept Selection

The Mintzberg study (1976) identified three routines in the selection phase: screen, evaluation-choice, and authorization. Three decision process criteria are proposed to have potential relevance in concept selection activities: accounts for full range of objectives, carefully weights pros/cons and examination of pros/cons prior to choice. Based on research associated with this study, Process Participation, Requirement Clarity, and Traceability are proposed as the variables with the most direct impact on the relevant decision process criteria.

	Accounts for full range of objectives	Carefully weights pros/cons	Examines pros/cons prior to choice
Process Participation	X		
Requirement Clarity		X	
Traceability			X

Process Participation represents the active involvement of participants in the complete decision process which includes requirement identification and idea development, in addition to concept selection. Inclusion in the decision process enables participants to understand how their function relates to other functions and also their function relates to the overall innovation (Van de Ven 1986; p.600). Process Participation enables development team members to incorporate a more complete range of objectives in their deliberations.

Requirement Clarity, by definition, includes the key requirements and their relative priorities. Without these conditions it would not be possible to evaluate pros and cons of concept alternatives.

Traceability of the decision process and outcomes was important for justifying the decision choices. In this study it was observed that the rationale for decision choices made early in the concept development process was required

during final concept evaluation. Traceability provides the vehicle for ensuring these factors are available for consideration during concept selection.

In addition to the use of the Process Participation Matrix, reflecting appropriate stages and steps, the Concept Selection Matrix can be used to diagnose final concept selection.

Concept Selection Matrix

The Concept Selection Matrix (Burchill et al. 1992) can be used to assess relative pros and cons of the generated (selected) concepts against the full range of objectives. Across the top of the matrix list the concept alternatives. Down the side of the matrix list the design objectives and constraints (organizational, technical, environmental, etc.). Select one concept to be the reference datum and evaluate the strengths and weaknesses all other concepts relative to the datum. In the example below, "1" is much worse than the datum, "3" is the same as the datum, and "5" is much better than the datum. In this example, concepts #3 and #8 are comparable with respect to satisfying customer requirements but concept #8 requires less risk and resources and appears to dominate.

	Reference Datum	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6	Concept 7	Concept 8	Concept 9
CR#1	3	3	5	2	4	3	1	5	3
CR#2	3	4	4	3	4	3	3	4	3
CR#3	3	4	4	2	3	4	2	4	4
CR#4	3	2	4	3	5	4	2	4	3
CR#5	3	3	5	2	4	3	1	5	3
Technology risk	3	5	2	4	3	5	3	3	4
Competitive risk	3	3	3	3	4	3	2	5	3
Resource rqmt.	3	3	4	2	4	3	1	5	3
Total	24	27	31	21	31	28	15	35	26
Average	3.00	3.38	3.88	2.63	3.88	3.50	1.88	4.38	3.25
Rank	7	5	2	8	2	4	9	1	6

Conclusion

The emphasis on TIME in the expression Time to Market clearly implies schedule related measurement and monitoring. However, the measurement and monitoring requirements associated with an emphasis on MARKET in the expression Time to Market is not so clear. In this chapter, I identify high leverage opportunities for management attention in the concept development process and propose relevant diagnostic devices. These measurement and monitoring devices are designed to assist management of the product concept decision process in time-to-MARKET oriented environments.

Chapter 6: Next Steps and Concluding Comments

This thesis presents Concept Engineering as a complete decision support process for enhancing product concept development, explores the dynamics of TIME vs. MARKET orientation in product concept development, and introduces Inductive System Diagrams as a variable development and integration enhancement for substantive theory generation. In this chapter, I will outline some potential next steps for continuing research in each of these areas.

Concept Engineering

Concept Engineering is currently being applied to approximately two dozen concept development efforts in ten organizations within the Center for Quality Management. The expanded application base includes small entrepreneurial concerns developing follow-on products, a Fortune 50 company on a large scale development effort, and a state government agency in the development of a new law. This application base provides a rich comparative setting to explore two broad investigative themes — Concept Engineering application contingencies and Concept Engineering process improvements.

Concept Engineering Process Improvements

There are two general process improvement themes related to Concept Engineering which can be explored. The first is improvement to the overall process, specifically focused on reducing the decision time. The second area of opportunity involves investigating enhancements to particular decision aids, specifically the requirement transformation process and Kano's analysis.

Concept Engineering Acceleration

The actual time to complete the Concept Engineering efforts in this study was substantially longer than the projected time. Applying the framework of Millson et al. (1992), it should be possible to identify potential areas for simplification, step and delay elimination, and parallel processing. The traditional roadblock for applying these acceleration strategies is the requirement for a thorough understanding of the targeted process. Fortunately, due to the combined experience of the User's Group, a fairly high level of Concept Engineering process knowledge exists. Additionally, the spirit of mutual learning, which is a cornerstone of the CQM, enables faster turns of the Plan-Do-Check-Act cycle through sharing of experiences across organizations. Therefore, within this environment, research to accelerate the development of market orientation within development teams would be desirable and possible.

Concept Engineering Decision Aid Improvements

A consistent observation during this study was the tendency for "requirement" statements to represent specific solutions rather than be a reflection of customer needs. The benefit of writing a requirement statement as a specific solution is reduced ambiguity. Unfortunately, the expression of a requirement as a functional solution severely restricts the designer's flexibility to make tradeoffs. It should be possible, using Likert-type scales for example, to assess the relative clarity and flexibility of requirement statements. These assessment could be made either by the team members themselves or by expert judges, either within or outside a organization. These data can be analyzed to assess their impact on development efficiency, effectiveness and innovation. The results could conceivably have a significant effect on product definition practices.

Kano's analysis (Kano 1984) helps us understand the relationship between the fulfillment (or non-fulfillment) of a requirement and the satisfaction (or dissatisfaction) experienced by the customer. Extrapolating Herzberg's (1966) motivator-hygiene theory to product quality characteristics Kano discovered that the relationship between fulfillment of a need and the satisfaction or dissatisfaction experienced is not necessarily linear but can be separated into four main categories: attractive, one-dimensional, must-be and indifferent. For example, when an attractive item goes unfulfilled the result is not dissatisfaction but the absence of satisfaction; in contrast, fulfilling a must-be item does not produce satisfaction. Currently, it has been observed that the construction of the questions and response scales associated with Kano's analysis is problematic for some development professionals. Additionally, Kano's analysis has not been systematically evaluated (or at least published in English language academic journals) in the context of traditional marketing research techniques. This is an area of investigation with potentially significant implications for product development resource allocation decisions. Preliminary work is underway for a collaborative effort between myself and Duncan Simester (1993 MIT-Marketing Ph.D. candidate) to conduct this more systematic analysis.

Concept Engineering Application Contingencies

With approximately two dozen Concept Engineering applications underway, covering the spectrum of market-technology uncertainty, a more thorough understanding of the contingencies associated with applying Concept Engineering can be developed. Current applications range from simple product line extensions, to radically new product concepts, to the development of new state laws. This environment can provide a rich comparative setting for the

development of contingency theories related to the product concept decision process.

All of the completed Concept Engineering applications have been product extensions for existing markets or existing technologies. However, some members of the User's Group believe Concept Engineering is best suited for developing products for new markets or technologies. One effort currently underway is pursuing a completely new product concept which they hope will create entirely new markets. Another effort is exploring potential market applications for new technology. These extremes, anchored by base cases in market-technology extensions leads to a potentially productive line of comparative research addressing the contingencies of Concept Engineering in particular and Market Orientation in general.

The effort to develop a new state law represents a service application in which constituencies have clearly conflicting positions. Prior Concept Engineering efforts have investigated diverse market segments, i.e. North America, Europe and Asia. However, it was assumed in those efforts, that if a clear conflict developed, multiple products would be developed or the decision choice would be made on the basis of the largest profit potential. In the case of the state law, it is not possible to develop multiple versions and it is not obvious how "profit potential" would be assessed. However, based on the work of the Harvard Negotiation Project (Fisher & Ury 1981), a dominant strategy for successful negotiations is to focus on the common interests instead of conflicting positions. In the state case, it has been possible to identify and articulate the common requirements of all constituencies in addition to their requirement differences. This case represents a potentially useful process application of Concept Engineering which has not been previously explored.

Time-to-Market Dynamics

Chapter Four of this thesis presented numerous propositions related to Time-to-Market dynamics which need to be validated. Some of the constructs identified as influential have been operationalized and investigated in other studies (). Other constructs (e.g. traceability, process participation, contextual awareness) have not been investigated and their significance on product concept development has not been statistically validated. Chapter 5 attempts to operationalize some of these variables from a managerial perspective which may be insufficient for a study attempting to apply traditional academic standards of statistical significance. Additionally, even after the hurdle of developing multiple construct operationalizations is overcome, the data collection process will be formidable.

My experience, at every company in this study, indicates that product concept development data is not systematically collected, if it is collected at all. Concept development activities are traditionally ad hoc and corporate product development data collection systems typically begin *after* concept approval not before. However, sufficient data may be available to assess the basic proposition that credible design objectives result in stable product concepts and the resulting reduction in misdirected effort reduces total development time.

Many companies use a product development phase review process with a formal "Concept Approval" stage. Conceivably at this point, a product definition exists which can be assessed for clarity and credibility, e.g. using Likert-type scales. Concept stability can be determined by reviewing engineering change notices assuming the records exist and it is possible to distinguish those engineering changes related to concept instability from those related to other sources, i.e. manufacturing requirements. This information can be compared to actual development time versus the original development schedule. This final

comparison is also dependent upon several assumptions regarding schedule forecasting reliability and project characteristics. However, a test for collecting the data described above, with the assistance of the company's Product Development Quality Assurance Department, was conducted in one company from this study. This limited data collection effort was difficult but does indicate the feasibility of investigating some of the Time-to-Market propositions utilizing empirical data.

Another path to model validation could be through system dynamic simulation. In the system dynamic approach, model validation follows from a multi-method analysis of computer simulations (Forrester & Senge 1980, Maas & Senge 1980, Richardson & Pugh 1981, Sterman 1984, Barlas 1989, Barlas & Carpenter 1990). System dynamicists have a long history of successful simulation analysis of development project management (see for example: Roberts 1964, Richardson & Pugh 1981, Abdel-Hamid & Madnick 1991, Sterman 1992). This previous work, assesses the impact of project changes on downstream development activities given initial tasks. However, as the existing work does not model the early concept development activities addressed in this research an opportunity exists for this research to extend previous dynamic models of project management.

The Time vs. Market inductive system diagram would serve as the conceptual model around which a formal computerized model can be built. Model formulation is the process of transforming the conceptual model into equations which increase the precision with which the system structure is specified. This precision, which is a necessary condition for conducting the computer simulation and analysis, also reduces the ambiguity of the causal-loop diagram (Richardson and Pugh 1981). For example, in this research it is proposed that reductions in Development Time would reduce Pressure for

Progress (Chapter 4, Proposition 18). Formulating this relationship might produce the equations below:

Pressure for Progress =
1 + (Expected Development Time - Scheduled Development Time) / Scheduled Development Time

Expected Development Time = Perceived Work Remaining / Perceived Work Rate

Perceived Work Remaining = Scheduled Work - Work Completed + Recognized Rework

Perceived Work Rate = (Work Completed - Recognized Rework) / Labor-hours Invested

These four equations clearly demonstrate how the formulation process fleshes out the skeletal structure of the inductive system diagram by specifying the system substructure of levels and rates. Formalizing the detailed dynamics of the entire Time vs. Market inductive system diagram will allow for a more precise definition of the relationships and subsequent simulation analysis of the propositions presented in this research.

Inductive System Diagrams

Two research themes could be pursued directly from the initial work on Inductive System Diagrams. First, a more extensive reliability assessment can be conducted and second, research related to enhancing the power of the diagrams should be pursued.

The reliability assessment of Inductive System Diagrams needs to be conducted on a larger sample of testers, some of whom are experienced qualitative researchers. Additionally, the assessment of the diagrams should be conducted by a panel of trained evaluators rather than a single person to increase result reliability. Finally, given larger sample sizes statistical analysis of the results can be conducted.

The rate-to-level limitations of causal-loop diagrams has been addressed by several systems dynamists through the use of flow diagrams (Forrester 1971,

Goodman 1974, Richardson 1981) and Policy Structure diagrams (Morecroft 1982). Prior attempts at representing this additional structural detail unfortunately make the schematic much more difficult to comprehend by the uninitiated. However, it should be possible for the analyst to employ these structural insights in the development and description of their models even if the detail is absent from the presentation schematics.

Additionally, Inductive System Diagrams can be extended by incorporating reference mode analysis into the development process. Reference modes clearly specify the dynamic behavior of interest in the system under investigation (Randers 1980, Richardson and Pugh 1981). Usually reference modes are based on actual historical data but they can also be created from expert assessments (Randers 1980, Richardson and Pugh 1981). Reference modes can be described either graphically or verbally but they must indicate the appropriate time dimensions of the variables described (Randers 1980, Richardson and Pugh 1981). Reference modes can help identify which variables should appear in the model (Randers 1980). Therefore, reference mode analysis could assist not only in the development of variables through theoretical sampling and coding but also in the elimination of variables during diagram integration.

Concluding Comments

At the highest level of abstraction, the basic lessons learned from the analysis of the Time-to-Market dynamics we were taught long ago: "Do it right the first time; because if you don't make time to do it right, you'll have to make time to do it over." One major contributing factor to the dysfunctional, unintended consequence of product concept development acceleration is the lack of product concept decision process understanding. Concept Engineering, as a complete decision support process,

clearly defines the steps and transitions associated with the product concept decision process and therefore has the potential for accelerating the development of market orientation within product development teams.

The development of Concept Engineering, the Time-to-Market analysis and Inductive System Diagrams all result from "cross-functional" collaboration. Without a common commitment to mutual learning between the initial companies and researchers at MIT, Concept Engineering would not have evolved into a complete decision support process. Without the companies granting the researcher extensive access to their product development activities, participants and managers, the rich comparative setting, essential for generating substantive grounded theory, would not have developed. Without the inter-disciplinary involvement of Operations Management faculty and Behavioral Studies faculty, the dialogue which resulted in Inductive System Diagrams would not have developed. Finally, without an overall commitment, by the thesis committee, to a partnership between industry and academia in the research of Total Quality Management, this thesis would not have developed.

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CONCEPT ENGINEERING

THE KEY TO OPERATIONALLY DEFINING YOUR CUSTOMERS' REQUIREMENTS

Document No. 7I
Revised September 1992

FOR INTERNAL CQM USE ONLY.
Comments should be forwarded to the Center for Quality Management for the next revision.

Table of Contents

Preface

This manual is designed to assist organizations in focusing on their customers' requirements in developing design concepts for products or services. Concept Engineering is a process for determining the customer's key requirements, creating a measurement strategy for assessing compliance with the requirements, and developing a strong product concept that satisfies the requirements.

Document History

The Concept Engineering method and manual have been developed in the true spirit of mutual learning and collaboration between member companies of the Center for Quality Management (CQM) and MIT. The material presented in this manual is the result of many Plan-Do-Check-Act improvement cycles applied to both the teaching and use of this method.

- The foundation for Concept Engineering began with a series of lectures by Professor Shoji Shiba at MIT and the CQM in the fall of 1990.
- The first outline of the process was developed by Gary Burchill (USN/MIT) in the winter of 1990.
- The first outline of the manual was developed by Gary Burchill (USN/MIT), Diane Shen (BBN), Ron Santella (GenRad), and Rich Lynch (Analog Devices) in the spring of 1991.
- The first version of the manual (CQM 7P),written by Gary Burchill (USN/MIT), Diane Shen (BBN), and Ron Santella (GenRad), was published in November 1991.
- The second version of the manual (CQM 7I), written by Gary Burchill (USN/MIT), Diane Shen (BBN), Erik Anderson (Bose), David Boger (Bose), Chris Bolster (MIT), and Bill Fetterman (Analog Devices), with editing assistance from Kenny Likis (BBN) and Deborah Melone (BBN) was published in September 1992.
- The authors would like to thank the development teams in BBN, Bose, Analog Devices, and Polaroid for their feedback on Concept Engineering and Dave Walden (BBN) for his encouragement and critique.

Critical Assumptions

Two critical assumptions have been made in the preparation of this manual: first, that the users of this manual are familiar with and competent in the KJ method; second, that the scope (minor product line extension, major new product introduction, etc.) of the development project has been at least preliminarily defined before entering step one, Exploration Planning.

If the first assumption does not hold, we recommend that KJ skills be obtained (through CQM courses) to maximize the potential benefit of this method. If the second assumption does not hold, i.e., the scope of the development project is very broad or vague, several iterations of the early steps of this method may be required before a market opportunity is identified.

The example used throughout this manual

This manual is designed to provide users with a quick introduction to the underlying concepts and methodology for each step. Steps are supported with examples, tips, and worksheets where appropriate. The appendix includes a glossary and further detail about selected concepts.

All examples come from a case study provided by Gary Burchill from a project on which he worked at MIT. The product developed by the MIT team was a saltwater flyfishing stripping basket.

A stripping basket is a device used by saltwater fly fishermen to collect their line before they cast out the line. Typically it is a store-bought or home-constructed plastic container with four sides and a bottom, which is strapped to the waist or chest of the fisherman. Before casting, the fisherman lays the fishing line into the container so the line will play out easily when the cast is made. The process of retrieving the line and placing the line in the container is called "stripping."

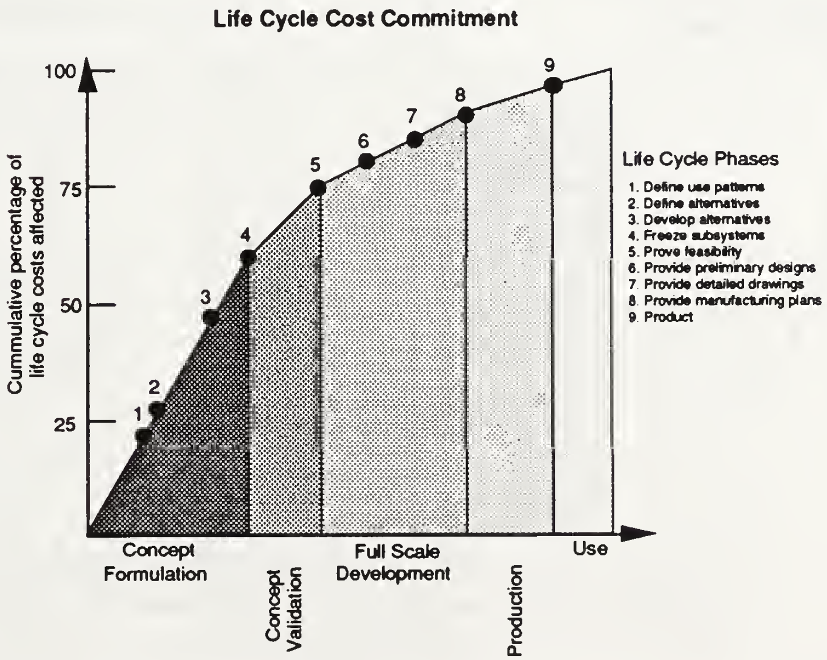
The goal of Gary Burchill and his MIT colleagues was to design a better stripping basket. Their basket was praised by the Outdoors Editor of the New York Times in his feature on Sunday, September 1, 1991. First year sales of their product has been ten times that of the product it replaced.

Other examples of the application of Concept Engineering are available from various CQM companies.

Introduction

Why Bother?

A recent study conducted by the National Research Council states that over 50% of a product's life-cycle costs are determined in the concept formulation phase of product development, and that approximately 75% of life-cycle costs are committed by the end of concept validation. Yet many companies spend little effort in these phases of product development and do not have effective methods for developing product concepts which they are confident will satisfy their customers. Unless people have an effective method for understanding the customers' needs and finding a product concept to meet them, companies will be locked into unsatisfactory concepts which drive the life-cycle costs of their products. Concept Engineering is a process designed to provide such a method.



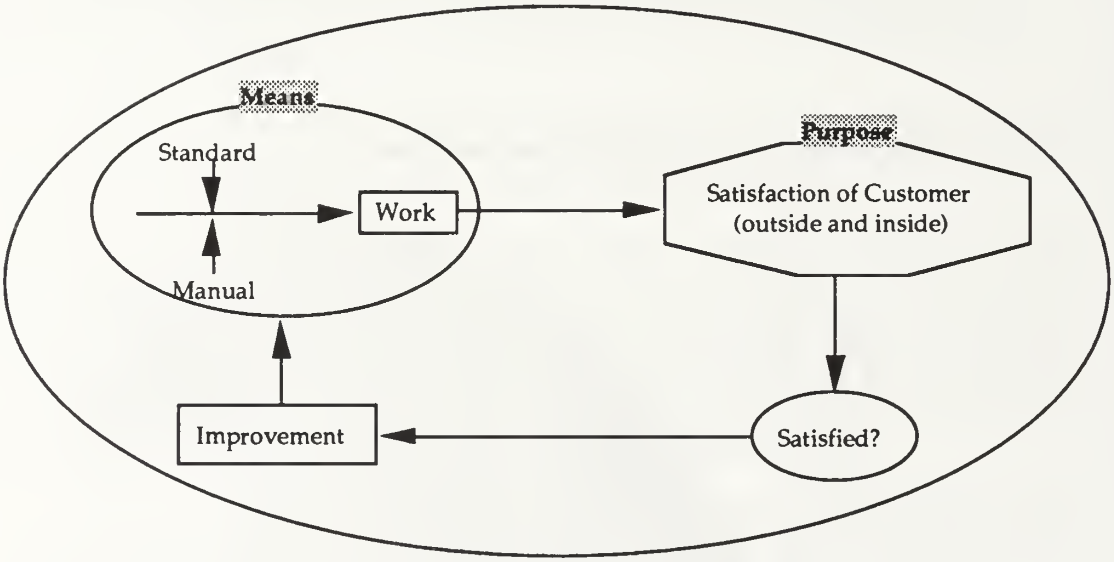
The National Research Council study outlines the troubled state of US engineering design skills. Interviews with senior managers associated with product development at CQM member companies reinforce the findings of the National Research Council report. These senior managers were asked several questions, one of which was to describe images that come to mind when they think about their product development process. These observations, captured by the KJ shown on the following page, emphasize the importance of establishing a concept engineering process.

Market-In Model

Concept Engineering is built on two models introduced to the CQM by Professor Shiba: Market-In and WV problem solving.

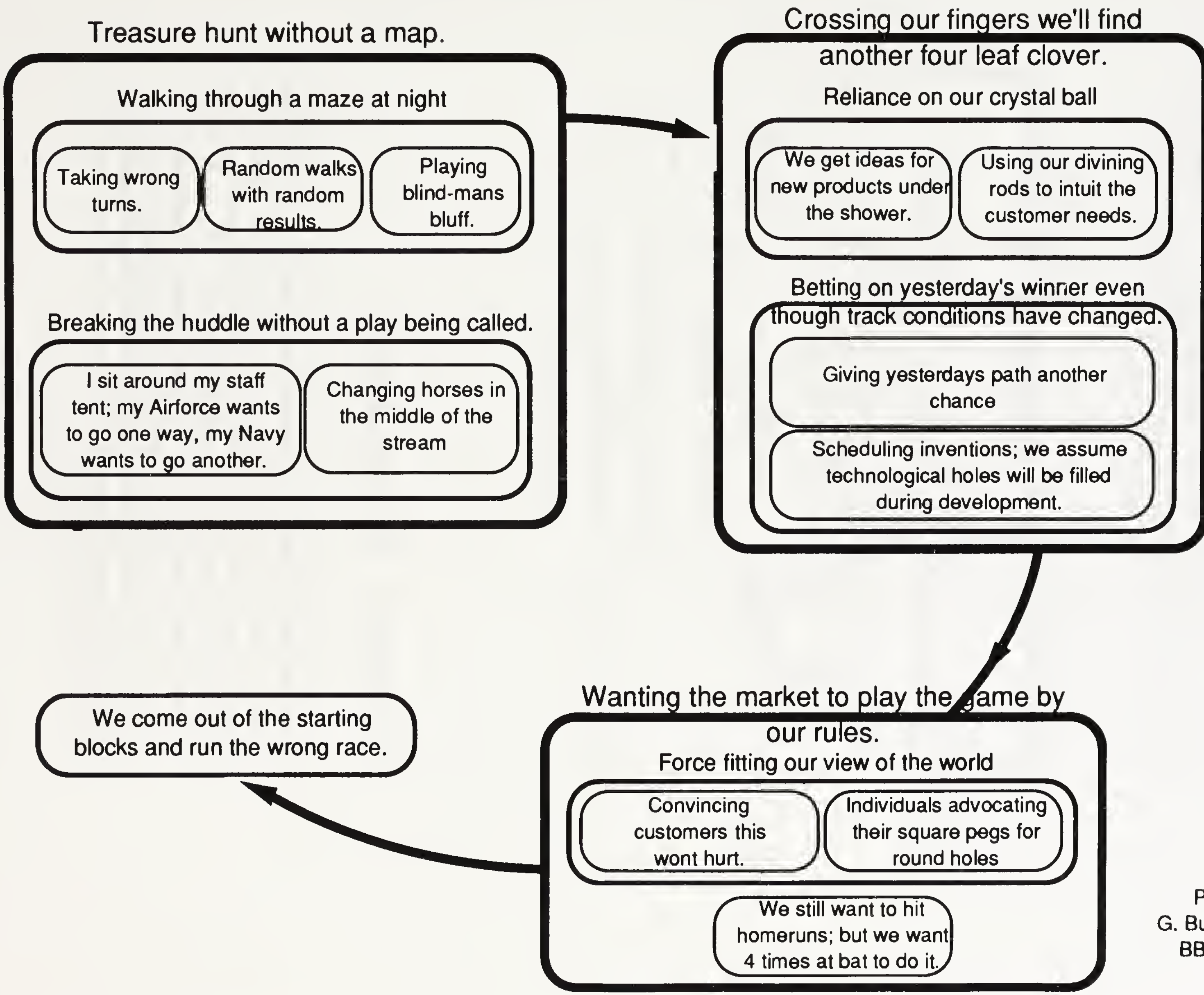
The "Market-In" attitude expands the horizon of how people and organizations view their job responsibilities. The output of one's effort is not the end objective of work, but instead the means by which to satisfy the customer. The end objective is customer satisfaction.

"Market-In"



In contrast, the product-out attitude defines its task as first designing and building the product or service, and then convincing customers that the product or service really meets their needs.

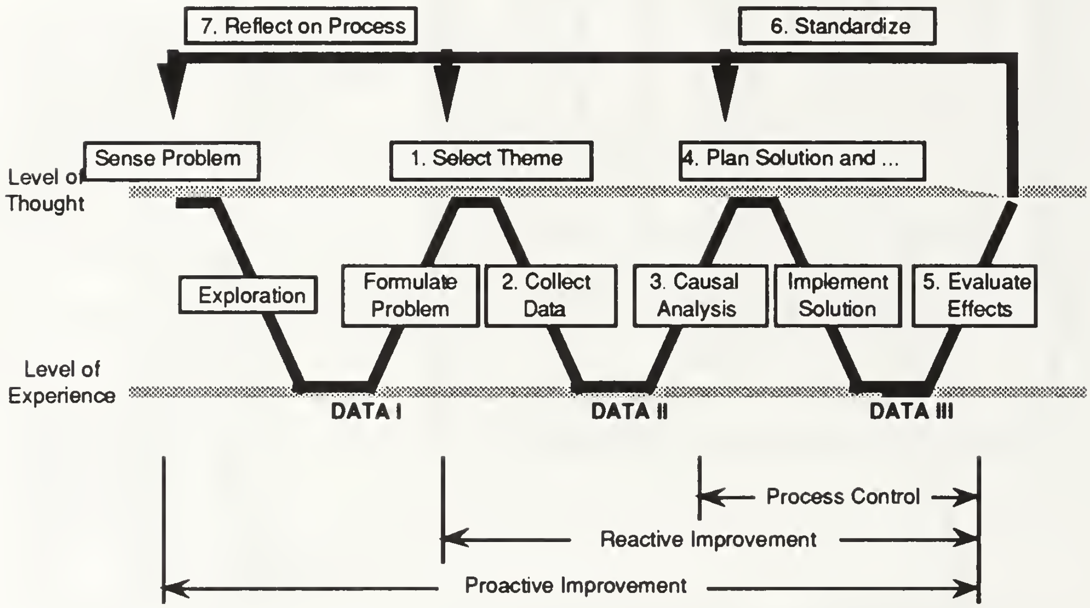
What are the images of product development activities within interviewed companies?



PD Image KJ
G. Burchill & D. Shen
BBN 23 AUG 91

WV Model

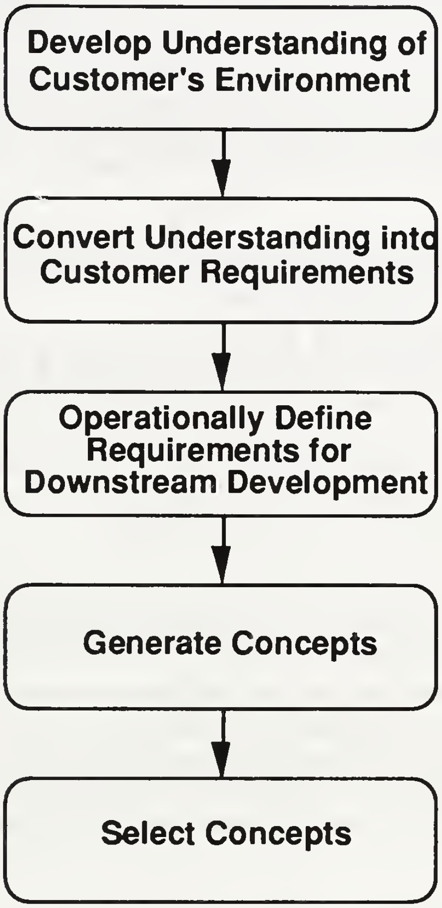
The WV model,Professor Shiba's extension of Professor Kawakita's W model, is usefulfor framing the product development process. It starts with a broad-based exploration of essentials and, by alternating between the level of thought (ideas and concepts) and experience (data), key issues are progressively defined in ever finer detail.



Concept Engineering

Concept Engineering is a customer-centered process for clarifying the "fuzzy front end" of the product development processthat comes before detailed design and implementation. It is a conceptual model, with supporting methodology, for developing product concepts. The process alternates between the level of thought and level of experience in a way that allows participants to understand what is important to customers, why it is important, and how it will be measured and addressed. It is a customer-centered process of data collection and reflection designed to develop product concepts that will meet and exceed customer expectations.

Concept Engineering Stages



Stage 1: Understanding the Customer's Environment

In stage 1, an exploration plan is developed based on the project scope, which identifies the customers to be visited and the information, broadly defined, which is being sought. The customer visits are conducted with an emphasis on collecting notes on verbatim customer statements and field observations. Then, the development team develops a mental model of the customer's environment to create a contextual anchor for downstream development.

Stage 2: Converting Understanding into Customer Requirements

In stage 2, the customer visit notes are analyzed to uncover the customer requirements (both explicit and latent) and the requirements are transformed from the language of the customer into the language of the company; from affective language into concrete statements. The vital few requirements are selected from the useful many and arranged in various combinations to create new insight.

Stage 3: Operationally Defining Requirements

In stage 3, characteristics of the vital few requirements are investigated with customers. Additionally, metrics are developed which will be used to measure quantitatively how well the requirements are met. Finally, all of the information and insight which has been developed is clearly and concisely displayed in one document.

Stage 4: Generating Concepts

In stage 4, the complex design problem is decomposed into smaller, independent subproblems. An exhaustive list of solutions (both feasible and infeasible) is created for each subproblem. Subproblem solutions are then combined to create solution concepts.

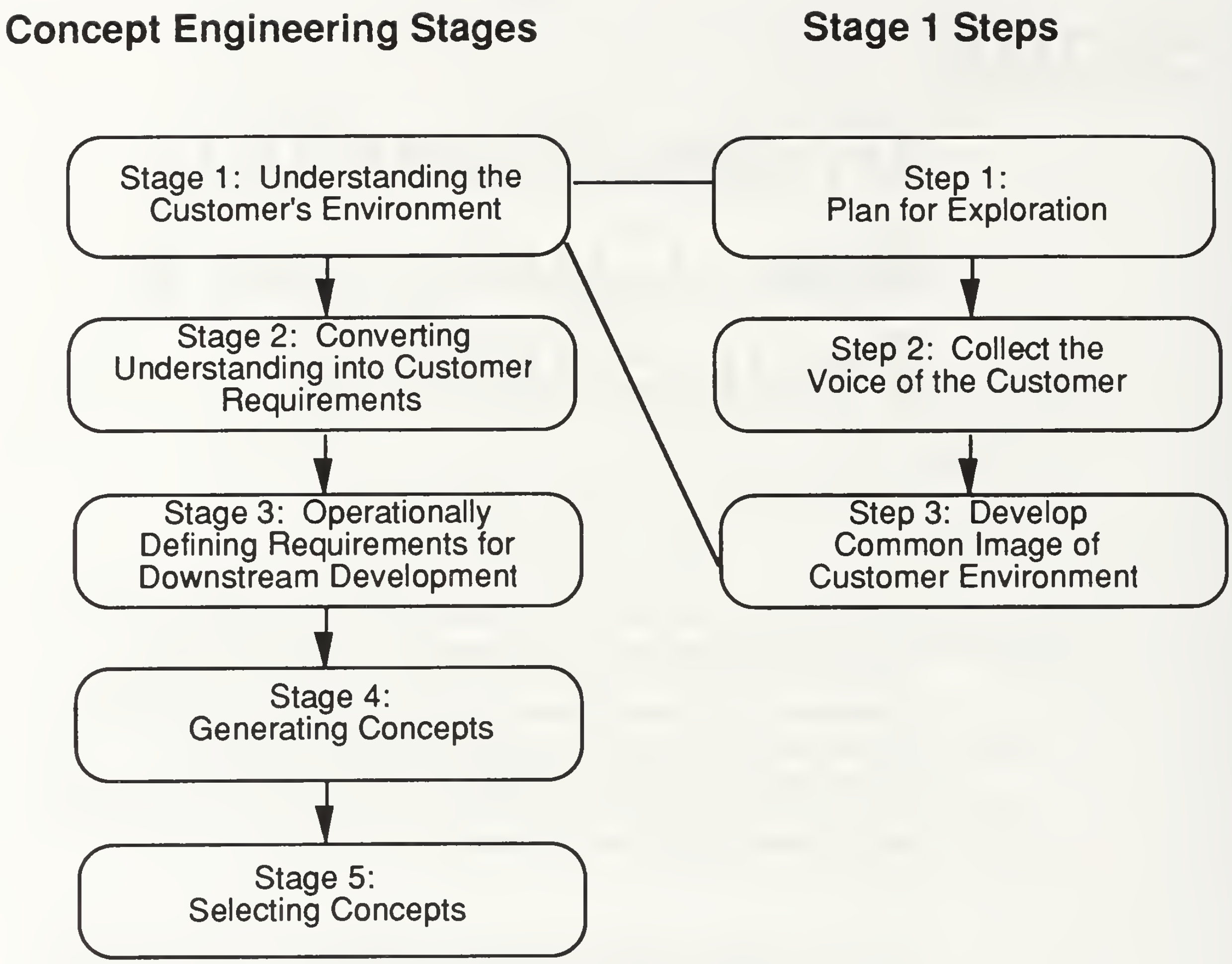
Stage 5: Selecting Concepts

In stage 5, the most promising solution concepts from Stage 4 are compared, in a structured process, against the customer requirements. The concepts which best fit the customer's requirements and the company's development capabilities are then selected for implementation.

Stage 1: Understanding the Customer's Environment

The first of the five Concept Engineering Stages is *Developing an Understanding of the Customer's Environment*. Critical to this stage is planning and scheduling of all downstream Concept Engineering activities. This stage consists of developing a plan for your team's exploration, doing the exploration, and using your team's interviews to develop a contextual anchor from the images of the customers' environment. This contextual anchor is actually a KJ diagram of images of the customer's environment. The Image KJ is a link to the customer's real world and acts as a way to ground all future decisions in the customer's environment.

As shown in the following figure, there are three specific steps included in Stage 1: Step 1, Plan for Exploration; Step 2, Collect the Voice of the Customer; and Step 3, Develop a Common Image of the Customer's Environment.



The five Stages of Concept Engineering are shown above on the left and will be repeated throughout this document as a way to keep track of where each stage is in relation to the entire process.

Step 1: Plan for Exploration

The purpose of Step 1 is for the team to discuss and understand the scope of the project and to develop a road map of future project activities. In this initial planning, your team agrees on the scope of the exploration theme, selects an exploration method, plans for and schedules the entire Concept Engineering process, and specifically plans for the data collection process. Planning for exploration will aid your team throughout Concept Engineering by supplying direction and purpose.

Understanding the Scope of the Project

Here the team must make a series of decisions defining the breadth of your exploration, starting with an exploration theme.

The exploration theme is an important device for setting project scope. For example, the following potential exploration themes would result in projects of different levels of scope and complexity.

A. "What are the most important customer requirements for flyfishing?

Or:

B. "What are the most important customer requirements for salt-water flyfishing?"

Or:

C. "What are the most important customer requirements for casting in a salt-water environment?"

Or:

D. "What are the most important customer requirements for a stripping basket?"

Example A defines the scope as the entire sport of flyfishing. Example B narrows the scope to salt-water flyfishing. C narrows it even further to casting in a salt-water environment, and D is focused specifically on requirements for a stripping basket.

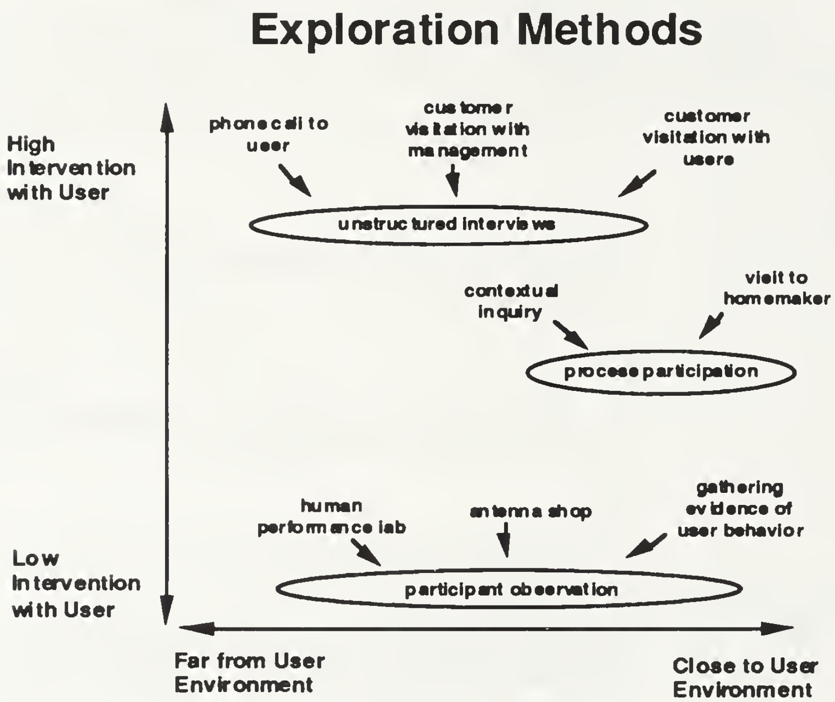
In example B, note how the focus of the team must change if only a few words of the theme are changed. If the word "salt-water" is added, the focus changes significantly.

The team should avoid limiting itself only to traditionally defined processes or services. Compare examples C and D above. Example D leads the team into the "solution space" of a stripping basket as an

answer to fishing line management problems. Example C, on the other hand, stays out of the "solution space" and remains in the "problem space" by directing the team to focus on the activity, not a solution to one of its problems. This subtle difference can significantly alter how the team develops its interview guidelines, thereby impacting what the team discovers. Whenever possible, do not limit your team's activity by adhering to conventional definitions of processes or practices.

Select Exploration Method

There are a number of methods for collecting data from your customers: in-person interviews, telephone interviews, laboratory observation, etc.. The figure below plots a number of different exploration methods on a two-dimensional map showing degree of intervention with the user vs. proximity to the user environment.



Unstructured interviews involve high intervention with the customer—an interviewer asking questions and follow-up questions based on the answers. These may occur either close to the customer's environment, as in a visit in the customer's office, or further from the customer's environment as in an interview conducted over the phone.

Process Participation involves some intervention and is by its nature closer to the customer's environment. Contextual Inquiry is a method used by Digital Equipment Corporation which involves sending engineers to the field to engage in a dialogue with the customers while they observe them using the product.

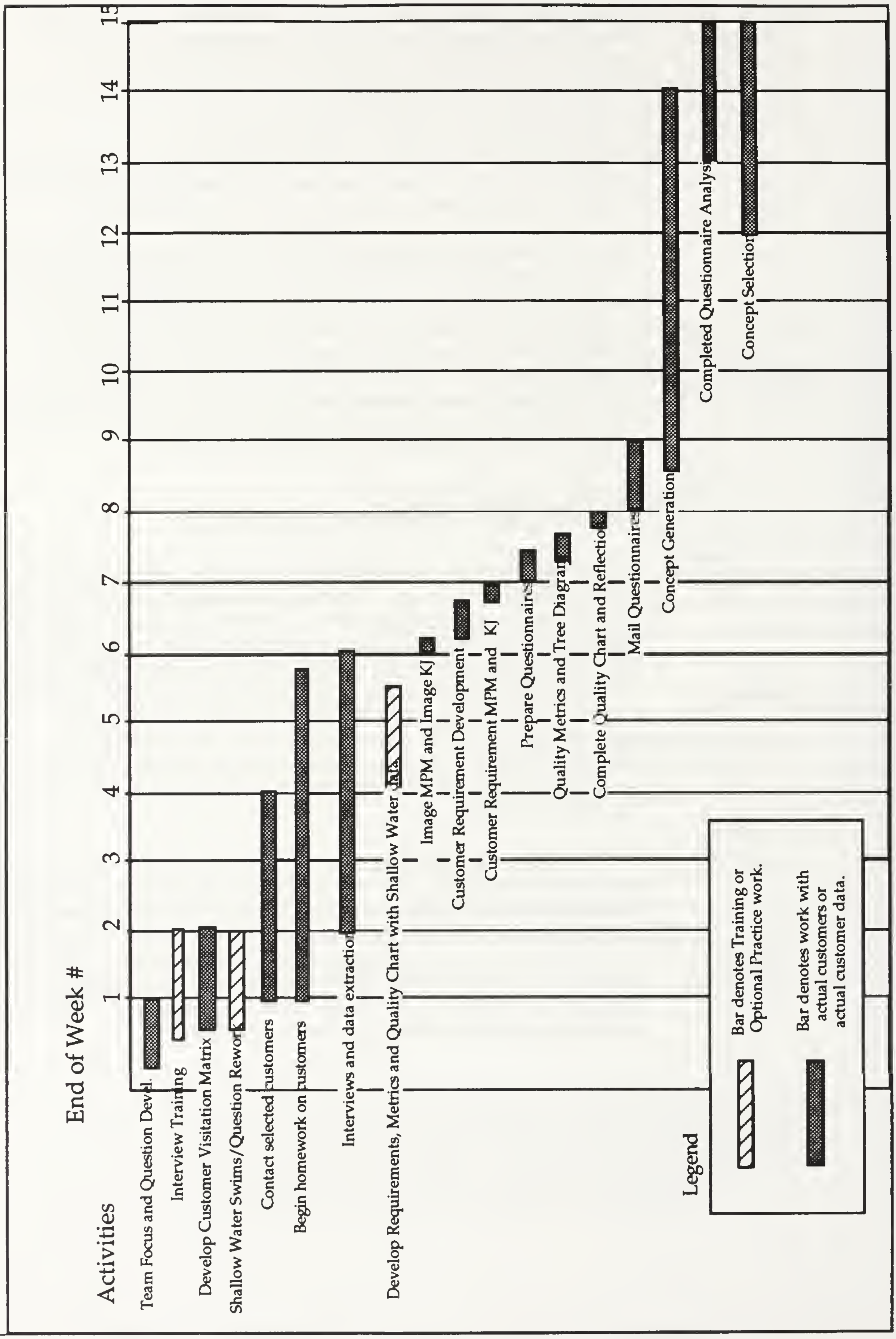
Participant Observation involves low intervention and can range from close to far from the customer's environment. Observing customers from behind a one-way mirror is an example of this kind of research.

Different methods are appropriate for different purposes. Keeping in mind that one purpose of Concept Engineering customer data collection is to extract images, that is, visualizations by customers using the product or service in their own environment, you should choose the method for exploration that best suits that need as well as other realistic constraints. In this document, we will focus mainly on in-person interviews at the customer's site, which include observations of their use environment. The major concepts and guidelines discussed, however, will be applicable to other methods as well.

Planning for Concept Engineering

It is important to have a well-designed plan of action for the entire Concept Engineering process. Concept Engineering consists of individual work and many team working sessions. Meeting coordination can be a powerful determinant of the team's momentum and eventual success. The team should agree upon a schedule and all members should plan for these meetings in advance. We recommend following Professor Shiba's advice to schedule a project completion date first and then plan backwards, filling in the activities and dates. The schedule for Concept Engineering needs one or two weeks of dedicated time after data collection in order to process the data. During some steps, weekly meetings are needed.

The Concept Engineering schedule will vary considerably depending upon the complexity of the team's project and the difficulty of reaching customers and scheduling interviews. However, all team-dependent activities should be scheduled into as short a time period as possible after the interviews are completed. The following guideline for task planning is a rough estimate of time required for each major task. The elapsed time is fifteen weeks. Some teams have completed Concept Engineering in fewer weeks; some have taken longer.


Gantt Chart of Concept Engineering Activities
Activities
End of Week #
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Team Focus and Question Devel.
Interview Training
Develop Customer Visitation Matrix
Shallow Water Swims/Question Rework
Contact selected customers
Begin homework on customers
Interviews and data extraction
Develop Requirements, Metrics and Quality Chart with Shallow Water data
Image MPM and Image KJ
Customer Requirement Development
Customer Requirement MPM and KJ
Prepare Questionnaire
Quality Metrics and Tree Diagram
Complete Quality Chart and Reflection
Mail Questionnaire
Concept Generation
Completed Questionnaire Analysis
Concept Selection
Legend
Bar denotes Training or Optional Practice work.
Bar denotes work with actual customers or actual customer data.

Planning for Data Collection

Planning the specifics of data collection requires a thorough understanding of the types of customers in the markets that your team intends to explore, as well as an understanding of the exploration methods your team will use. Deciding the who, what, when, where, and how of data collection enables the team to consider how they will divide up market segments.

How Many Interviews?

Open-ended customer interviews are intended to explore the market and learn about customer needs. One of Professor Kawakita's principles emphasizes the importance of using a small number of qualitatively rich cases. This principle is supported by the work of Professors Griffith and Hauser, who hypothesize that 10 to 20 interviews are sufficient if conducted with knowledgable customers. Twelve to fifteen interviews is a target that is realistic and not overly cumbersome. However, if you believe you have distinctly different market segments, you may need a minimum of 10 interviews per segment.

Which Customers to Select?

Diversity in selecting customers is important in order to explore the market broadly. A Customer Selection Matrix, shown below, is a helpful tool to search for diversity among the customers you visit.

Customer Selection Matrix

		Lead Users	Demanding Customers	Happy Customers	Unhappy Customers	Customers we had but lost	Customers we never had
New England Salt-Water FF	name 1						
	name 2						
	name 3						
	name 4						
Carribean Flats FF	name 1						
	name 2						
	name 3						
	name 4						
Salmon Fly-fishing	name 1						
	name 2						
	name 3						
	name 4						
Steelhead Fly-fishing	name 1						
	name 2						
	name 3						
	name 4						
Trout Fly-fishing	name 1						
	name 2						
	name 3						
	name 4						
	name 5						

Categories of Customers

The categories down the left side of the matrix cover typical market segments. These may be geographically based, or based on any other category of market segmentation that is typical for your field of exploration. In the example above, fly-fishing markets can be segmented into: New England Salt-Water Flyfishing, Caribbean Flats Flyfishing, Salmon Flyfishing, Steelhead Flyfishing, Trout Flyfishing and Distributors.

At the top of the matrix your team thinks about your customers in a slightly different way and lists categories of customers, for example, Lead-Users, Demanding Customers, Happy Customers, Unhappy Customers, Customers We've Had but Lost, and Customers We've Never Had. The categories across the top of the matrix will help ensure that you are not simply approaching those customers who are easiest to approach, but those who are, potentially, most useful to your Concept Engineering process.

Lead Users, a concept developed by Professor Eric Von Hippel, have needs which typically foreshadow the general demand of the market. Additionally, they often have some prototype experience; that is, they have worked around existing product constraints to solve their problem. Therefore, Lead Users are particularly helpful in exploring the opportunities, as their prototype experience gives them a potentially greater ability to perceive and express needs.

Using the Matrix

Once the categories are listed, begin filling in customer names in each of the cells. Once all cells are filled in, select customers who are most appropriate for your project.

It is not necessary that the team visit and interview a customer from each combination of categories; indeed, that would put the team well over the suggested 12 to 15 interviews. A general guideline from Professor Ed McQuarie, Santa Clara University, is to have three to four interviews in cells you consider most important and fewer, if any, interviews in the others.

Who Conducts the Visits?

Interviews should be conducted in pairs, preferably by two people from different functions in the organization, i.e., one from marketing and one from engineering. There are many reasons for using cross-functional interview teams. For example, the marketing person may be more likely to focus in on the customer's statements of needs; the engineer may focus on the customer's solutions to a difficult technical problem. Together they have a better chance of gathering a 360-degree view of

the customers world. Additionally, as engineers seldom spend time in the field, this is an excellent opportunity to put the engineer face to face with the customer. This opportunity to visit and explore the customer's environment can build the team's empathy for the customer.

Exploration Principles

Market exploration through in-depth, open-ended customer interviews is a marketing research method which is different from methods intended to validate market hypotheses. Customer interviews can be used to develop hypotheses; traditional market research methods are still needed to test hypotheses, gather demographic data, etc. As a different type of market research, customer interviews follow different guidelines than quantitative market research tools. Professor Kawakita has developed five guiding principles for collecting qualitative information:

1. Take a 360-degree perspective. Walk around the situation from many different angles. Do not have a hypothesis about what you will hear; keep an open mind in order to explore broadly.
2. Have a stepping-stone agenda. Do not schedule customer visits back to back. Allow for the possibility of an unexpected visit opportunity. Use an interview guide loosely; follow the path the customer creates.
3. "By Chance". Utilize chances – but you can create chances if you are sensitive ; concentrate on the problem or opportunity in order to see chances to learn more. Louis Pasteur says, "chance favors only the prepared mind."
4. Use your intuitive capability. Intuition is the tool of discovery, logic is the tool for proof. Human intuition has great capability to find somethind new. If your intuition is telling you to pursue a topic with a customer, follow your intuition.
5. Qualitative vs. quantitative data. Numbers are not so important; cases and personal experiences are important. Diversity of insights is more important than the number of times you hear the same information.

In addition to Kawakita's principles, Peter Drucker's work on sources of innovation is a helpful guide. Drucker states that innovation is most likely to be found in surprises, incongruities, and process holes. Customer interviews can be rich sources for discovering and exploring these innovation opportunities with a 360-degree perspective.

Developing the Interview Guide

The Interview Guide is a small set of open-ended questions and sub-questions you can use as a guide during the interviews. It is only a guide, not a strict questionnaire that must be rigidly followed. It acts as a reminder to ensure that you cover all of the important topics. This is not to suggest that the guidelines restrict you from taking a different path during the interview. Indeed, it must be left to the interviewer to determine when there is an opportunity to veer off from the guidelines, either for broader exploration or to gather specific, detailed information. These opportunities usually occur in later interviews when the interviewers' sensitivity and interview skill is increased.

The questions which make up the Interview Guide can be generated in a number of ways. The Net-Touching process, outlined below, helps ensure that appropriate breadth and depth of coverage is developed.

1. Brainstorm answers to the question, "What do we want to learn on our visits?" Write each thought on a 3"x3" label. (This could be done as individual work before the group meets).
2. Prepare the meeting room as you would for a KJ.
3. Have the team leader or facilitator randomly select a label, read it out loud, and post it to the board. They then ask other team members to provide labels of similar questions.
4. When there are no more labels on the topic, write a title for the group, in the form of a question, which is one step higher on the ladder of abstraction.
5. The team leader asks for a label on a new topic.
6. Continue this process until all original labels are posted to the board, either in groups or as lone wolves.
7. Continue grouping (by classification) the question-groups, writing titles in the form of questions until a small number (4 to 6) of groups are formed.

Professor Shiba suggests ensuring that the questions cover the following categories. For any that are missing, add a new question.

- <u>Past problems or weaknesses</u> of the product or service —these are useful in providing insight into the customer's perceptions. For example: What are the weaknesses or problems you've experienced with this (or this type of) product or service?
- <u>Current considerations</u> associated with purchasing or using the product or service — these can be helpful in understanding the customer's expectations. For example: What do you think of when selecting this product or service?
- <u>Future enhancements</u> of the product or service —this provides additional emphasis and detail on points previously discussed. For example: What new features might address your future needs?

- Scenes or images of the customer's use environment —these are essential for grounding all future development actions in the context of the customer's experience (Step 3). Some examples: What are the images that come to mind when you visualize the use of...? or, When you think about using this ... what are the scenes that come to your mind, or, If I had a video camera and recorded a scene of you using this product (or working in the lab, or struggling with a critical problem, etc.), what would I see?

Compile the questions and sub-questions from the net-touching, adding any that come from reviewing the four categories of questions, into an interview guide. Think about a possible sequencing of the questions.

Interview Team

Interviews should be done in pairs: that is, two people interviewing one customer. One of you is the questioner, the other takes *verbatim* notes of the customer's responses to questions. Notetaking does two things: it shows respect for the customer, and it captures the data. The questioner takes notes of observations and areas to explore. In general, the questioner stays engaged with the customer and does not take too many notes. The notetaker stays focused on writing the actual words of the customer (not a summary of the customer's thoughts) and should not ask too many questions. These roles of interviewer and notetaker can be reversed between interviews, but should not be changed during an interview.

Practicing

Practice interview sessions have proven to be powerful in developing interview skills. Role play an interview. Have one person as an interviewer, one as a notetaker, and one as a customer. Conduct the entire interview using the interview guide. Watch your body language to be sure you portray a message of interest throughout the interview. Debrief after the interview and discuss what worked well and didn't work well. Rotate roles so that each team member gains experience as a questioner and as a notetaker.

Swim in Shallow Water

Do a dry run of the interview process on familiar customers or internal people, and revise the guideline as necessary. This is a critical step; do not underestimate its importance.

Doing Your Homework about Customers

In order to show respect for the customer, before conducting visits , make sure that you are well briefed in the background of the customer, the products or services the customer purchases from your company, and additional information that may be meaningful to your visit. Understanding what your customer's business is and demonstrating that

understanding in the interview process will go a long way toward establishing a comfortable rapport for the visit.

Tips

- Make sure to include the sales force as appropriate in planning and scheduling customer visits.
- Do as many practice interviews and shallow-water swims as time allows. The investment will pay off when you are doing customer interviews. The team will spend much time and effort on doing the interviews, and the success of the future product depends upon the data brought back from the interview.

Completion Checklist

At the end of Step 1 you should have:

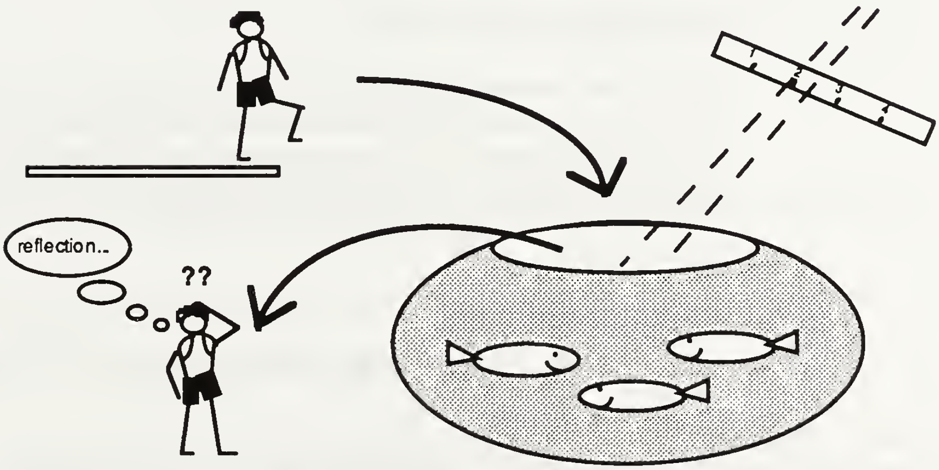
- A schedule for the project
- A Customer Selection Matrix complete with the names of customers to be visited
- An interview guideline which has been tested
- Team members with training and practice in interviewing skills
- A list of who will visit whom

Step 2: Collect the Voice of the Customer

The purpose of this step is to gather the customer data which will drive all subsequent Concept Engineering activities.

A useful concept for this step is Professor Shiba's "Swimming in the fishbowl." It depicts the fishbowl as the user's (customer's) environment, with the swimmer (interviewer) entering, swimming around, exiting, and reflecting upon what was learned. In contrast, traditional market research looks at the market with developed hypotheses, essentially looking from the outside and measuring behavior in the fishbowl. Customer Visits and Contextual Inquiry are methods by which people who will make decisions about the product or service jump into the fishbowl, swim around and see what is going on, and then jump back out of the fishbowl to analyze what they saw.

Swimming in the Fishbowl



Scheduling Visits

The interviewing process requires the careful balancing of the interview schedule around customers' availability and your needs. Generally the team members will have to adapt their schedule to the customers'.

Prior communication with the customer is important to the success of the interview. A letter confirming the date, time, purpose, and the agenda should be sent to each customer. (It is also a nice touch to fax the interview guide to the customer a few days before the visit.) The degree to which you are open about your intention, and the degree to which you and your team honor the customer in a number of ways will determine the extent to which the customer will be open and honest in return. This effort at building rapport can be particularly valuable if you need to make additional contact. Honoring the customer at all times should be of highest priority.

Schedule 60 to 90 minutes for each interview, but be flexible. If you schedule more than one interview at a site, allow for approximately 2 hours between interviews. Even if you intend to conduct only one interview in a day, block off at least 90 minutes after the interview for debriefing with your interview partner. Preferably this will occur immediately after the interview concludes; conduct the debriefing in the parking lot if necessary.

Conducting the Visits

Visiting and interviewing customers is not a task to be taken lightly. Remember that every time you interface with a customer in the Concept Engineering process, it is for *your* education, not the education of your customer. Customer interviews are not opportunities for sales calls. It's your listening skills, not presenting skills, that are going to be tested on these visits.

In fact, the listening required on a customer visit forces you to:

- Be open and receptive to the customer's opinions and feelings.
- Suspend all judgments.
- Accept whatever the customer says 100%; never argue!

One of your goals in the interview is to get beyond the first or obvious answers to the essential data. Often the customer's first response to a question is just the tip of the iceberg. Following up with probing questions is necessary to get to the bottom of the iceberg where the majority of the data is; explore the customer's thoughts in depth.

For example, the customer might give you a solution idea. Below the tip of the iceberg is the problem the customer is trying to solve. Explore this topic until you understand the nature of the problem in addition to the solution the customer has mentioned. The customer's solution should be recorded because it may be useful in Generating Solution Concepts, but in order to learn about the customer's need, you must understand the problem hidden below the solution.

Finally, remember to thank the customer for the opportunity they have given you to learn.

Debriefing

As was mentioned earlier, you should schedule 60 to 90 minutes after each interview to debrief. You may end up using the time to conduct a spontaneous interview. If this happens, you should still debrief as soon after the interview as possible.

Follow these steps immediately after the interview:

1. Make a copy of the notes.
2. Discuss general observations for a few minutes.
3. Read notes carefully, filling in gaps with the customer's actual words if you can recall them.
4. Discuss the interviewer's questions and follow-up questions. Note what worked well and didn't work well.
5. Discuss and note insights about your customers, their environment, their needs, etc. that you gained from this interview.
6. Think about improvements to the interview guide and note these.

When you get back to the office:

7. Share observations with other team members.
8. Type up the verbatim customer notes, creating a transcript of each interview as soon as possible.

Image Collection

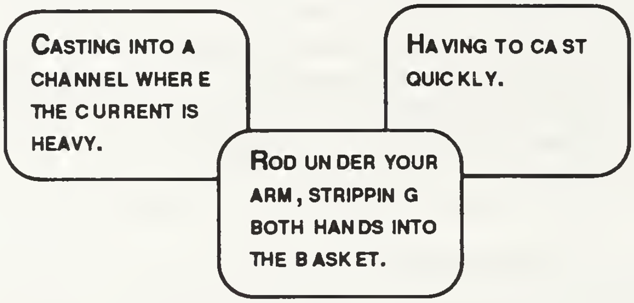
As discussed earlier, images are the scenes or descriptions of product use or the emotion associated with the product's use that are generated in the interview process. They may also include your observations.

Read through each customer interview transcript and pull out the images of the customer's environment by looking at each customer statement and thinking about whether it is a past weakness, present consideration, future enhancement, or an image of the customer's

environment. At this point you are looking for images of the customer environment, e.g., images of the customer using the product or doing a task. Later you'll come back to the interviews and pick up the other customer voices which will be used to generate customer requirements.

Write each image on a 3" x 3" Post-It Note with a black pen. Use the customer's actual words or your observations. Don't worry about including some statements that may also fit into another category (e.g., a past weakness). If in doubt, write it down. It is not unusual after all of the interviews are completed to have 100 or more images.

Examples of images from the Stripping Basket Case Study are below.



Tips

- Debrief as soon as possible after each interview and use this time to improve your interview skills and intuition about the customer's needs.
- Remember to leave flexibility in your schedule to take advantages of the offers for plant tours, interviews which go longer than expected, etc.
- Schedule time for the team to get together during the interview weeks to share observations and insights.

Completion Checklist

At the completion of Step 2, you should have:

- Transcripts from each customer visit
- Image statements written on 3x3 "Post-It" labels

Step 3: Develop a Common Image of the Customer Environment

The purpose of this step is for the team to create a common mental map of the customer's environment. This map is the primary device for keeping the team grounded in the customer's use environment. The Multi-stage Picking-out Method was developed by Professor Kawakita as part of the KJ process. It is used to select the best images collected in step 2 for subsequent use in creating the Image KJ. The image KJ follows from the work of Professor Ohfuji and colleagues, and is a critical component of the requirement statement development process described in Step 4.

Gather Image Statement Labels

During Step 2, Collecting the Voice of the Customer, image statements identified from each interview were transcribed onto 3"x3" Post-It labels. These labels should be collected and posted on a large table or to a wall. Use the Multi-stage Picking-out Method (MPM), CQM Document 5P, to reduce the number of images to between 24 and 30. This number is a manageable size for the Image KJ. When the number of images increases toward 30, the time required for the KJ increases dramatically.

MPM Selection Criteria

The following criteria for selecting images for the Image KJ should be displayed prominently next to the MPM work area and repeated before the start of each round.

1. Images should reflect the personal experience of a user. They are often written in first person. For example: "I come home from fishing and throw my basket by the porch stairs and there it stays."
2. Images should be capable of standing by themselves without amplification or explanation from the author. For example: "Fishing from the platform on the bow of the boat."
3. Diversity of images is essential. It may be better to select an image label of slightly inferior quality according to Criteria 1 and 2 in order to obtain coverage of an area not yet covered.

Select Most Significant Images

MPM is a tool which involves the team in choosing the vital few from the useful many. The focus is on picking up strengths, not eliminating weaknesses. Select a target number of Image labels usually around 24, and a cutoff number (1/3 more than the target). The theme is usually: "What are the scenes or images of the customer's environment?" The theme and selection criteria should be posted next to the labels.

We assume familiarity with the use of MPM. See CQM Manual 5P for detailed instructions.

In the initial ("multi-dot") rounds, every participant can select any and all the labels they want to keep by marking a small dot on the lower right corner of the label with a red pen. There is no time limit to any round or limit to the number of labels you can mark. However, it is important to recognize that the number must be reduced and you need to be successively more selective. The initial rounds are completed when the number of labels remaining is approximately equal to the cutoff number (around 32).

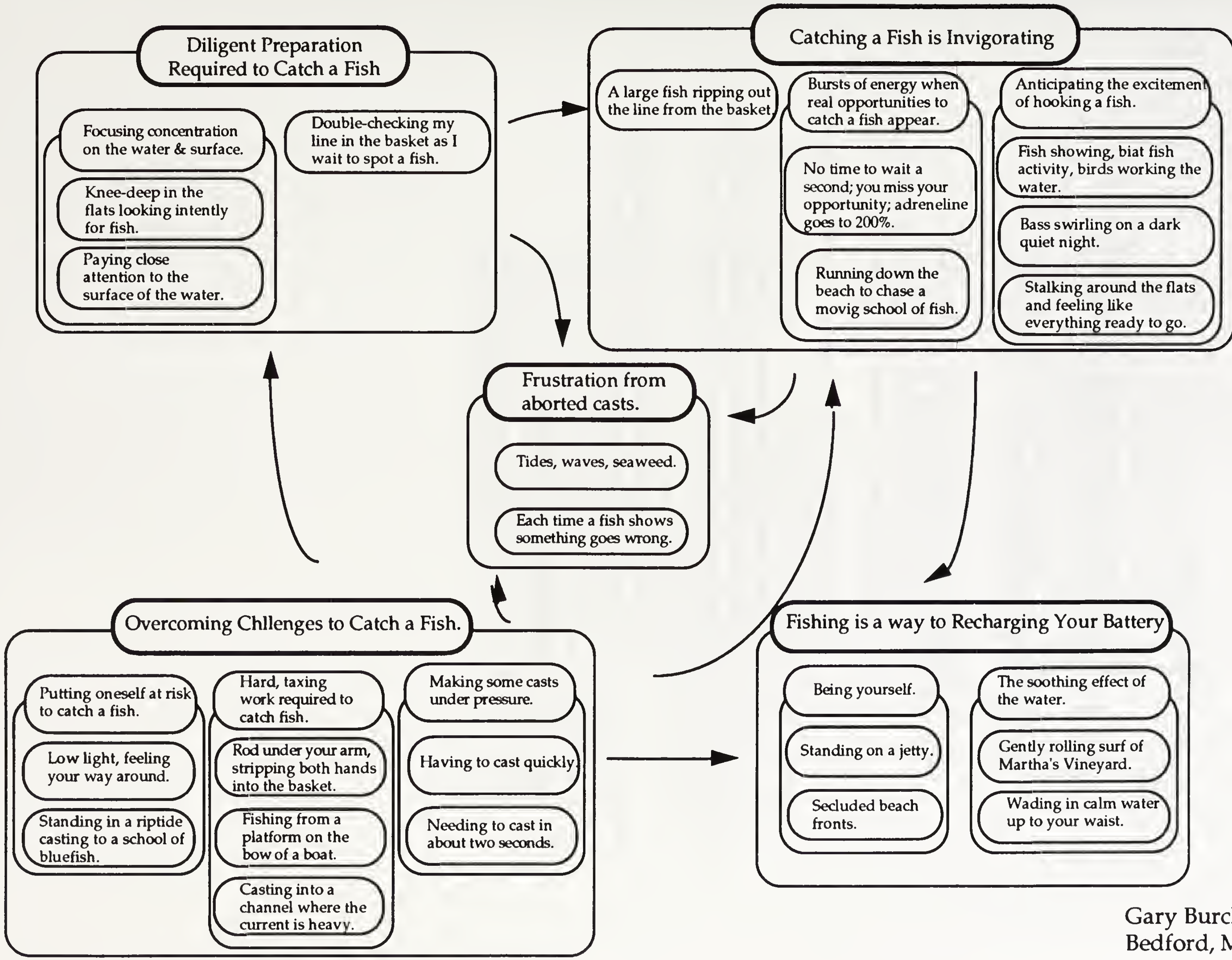
In the final ("limited-dot") rounds, you can select only a predetermined number of labels. This limit is usually calculated by dividing the target number by the number of participants. In these rounds, you select in order, each label being read out loud before the next in line selects. When everyone has selected their allotted number of labels the target number should have been reached and the selection process is complete.

Create Image KJ

The Image KJ is slightly more difficult than a traditional KJ. The KJ process, as outlined in the CQM KJ manual (Document 2P), provides the basic KJ steps. Several additional guidelines are provided for Image KJs:

- The theme for the image KJ might be: "What are the scenes or images of the customer's environment."
- The scrubbing step should not change the words on the label. If a label requires clarification the author should provide additional context by referring to the appropriate interview transcript.
- The titles to the groups should continue to reference the customer and their environment. Titles which contain the product as the subject tend to be requirement or solution oriented rather than descriptions of the environment.
- There is no need to vote on the most important groupings.

What are the scenes or images which come to mind when you visualize Saltwater Fishing?



Gary Burchill
Bedford, MA

Reflection

Upon completion of the Image KJ, it is time for your team to pause and reflect upon what you have learned. It may be that you have learned you still need information from other customers who were excluded, or that you learned something using this process that may not have been uncovered otherwise. You should also reflect on the process and how it might be improved the next time.

Tips

- Avoid selecting Images which are highly abstract and don't give you a good picture of the customer's use environment.

- Images which contain or evoke emotion are preferable to those which are purely descriptive.

- Watch for a tendency to migrate from customer to product orientation during title development. (Titles will start looking like customer requirements instead of images of the customer's environment).

- Be careful of clarification discussions which are not anchored in the interview transcripts; they can lead to misinterpretations.

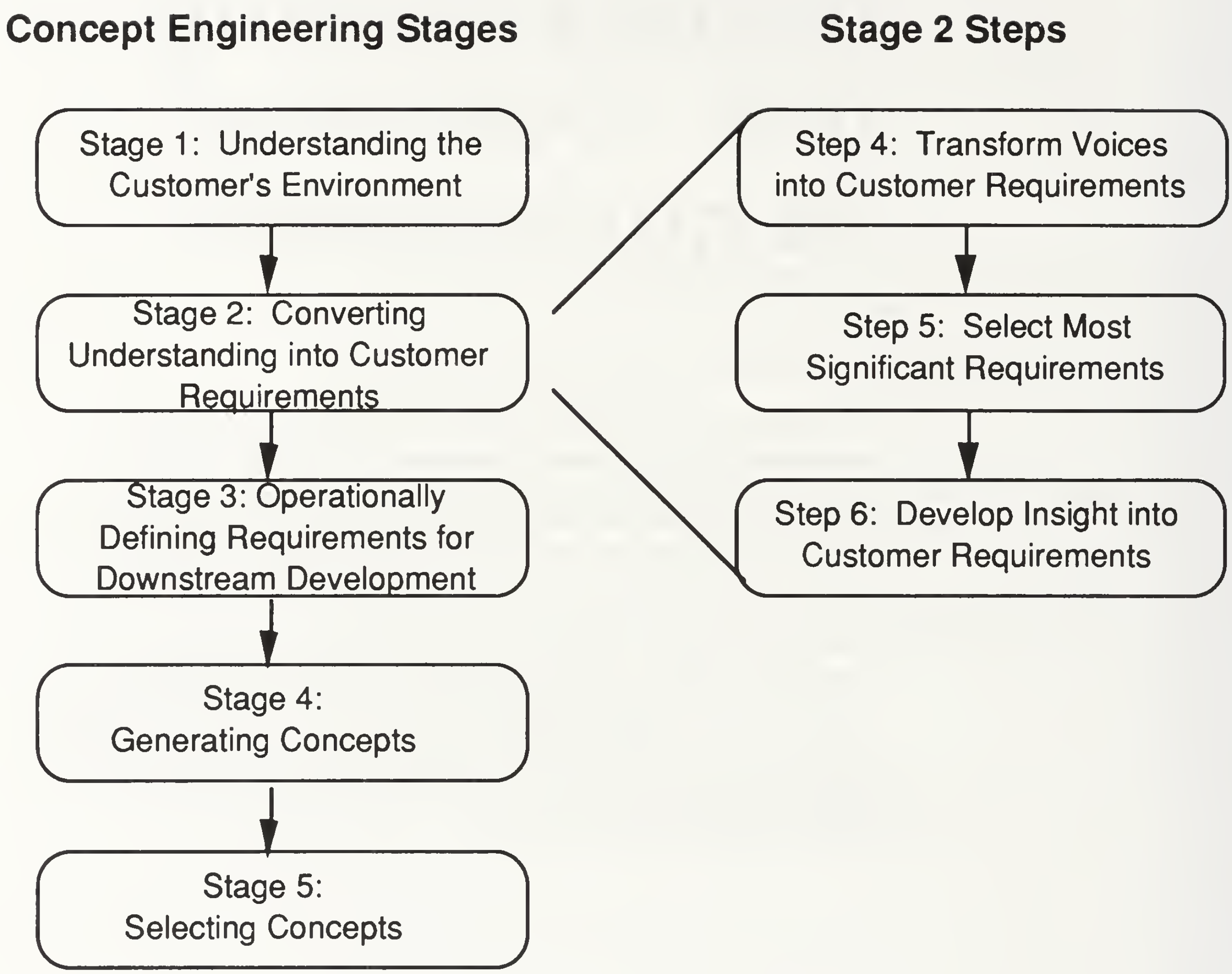
Completion Checklist

At the end of this step, the Image KJ should be complete.

Stage 2: Converting Understanding Into Customer Requirements

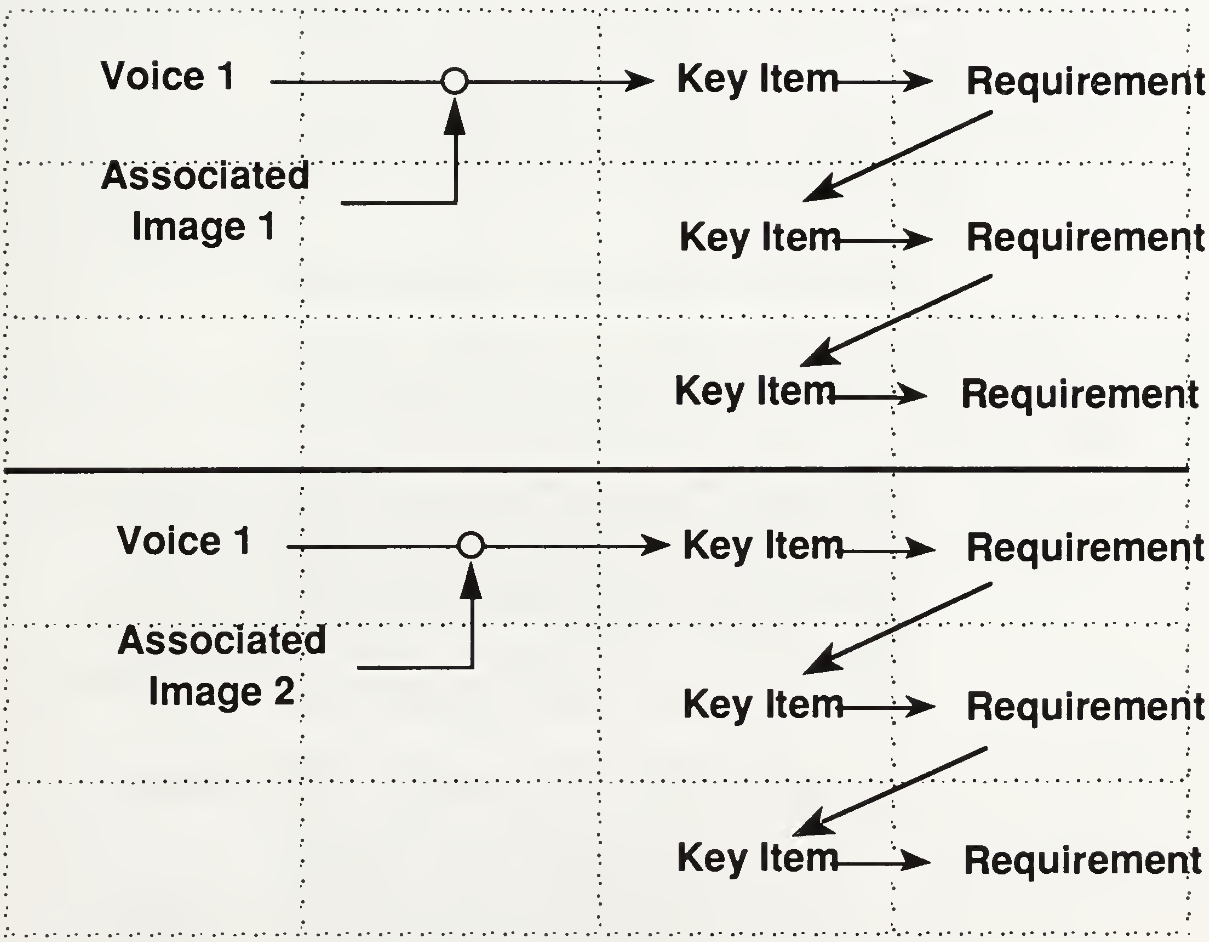
The second of the five stages in Concept Engineering is *Converting Understanding into Customer Requirements*. This stage distills what was learned from the customer exploration into a small set of well understood key customer requirements. The Image KJ developed in Step 3 will be used as a contextual anchor to ensure that the requirement statements developed are consistent with the customers' environment.

There are three steps in Stage 2. In Step 4, the transformation method converts the customer's language, often laden with emotion, into a requirement statement better suited for use in downstream development activities. Step 5 uses the Multi-stage Picking-out Method to identify the vital few requirements from the useful many. Step 6 employs the KJ method to develop new insight and team consensus regarding the relationships among requirements.


Concept Engineering Stages
Stage 2 Steps
Stage 1: Understanding the Customer's Environment
Stage 2: Converting Understanding into Customer Requirements
Stage 3: Operationally Defining Requirements for Downstream Development
Stage 4: Generating Concepts
Stage 5: Selecting Concepts
Step 4: Transform Voices into Customer Requirements
Step 5: Select Most Significant Requirements
Step 6: Develop Insight into Customer Requirements

Step 4: Transform Voices into Customer Requirements

The purpose of this step is to develop customer requirements which are unrestricted and unambiguous. Requirement statements should reflect the customer's need, *not* potential solutions to the need which inadvertently restrict the requirement. Requirement statements should minimize ambiguity. When requirement statements are expressed in ambiguous terms that allow for diverse interpretations, subsequent development activities can be both inefficient and ineffective. The methodology links each selected voice with an appropriate image or images from the Image KJ developed in Step 3. Key items (key thoughts or essential ideas) from the image-voice association are extracted and converted into requirement statements through an iterative refinement process. Translation guidelines are used to develop requirement statements which are unrestrictive and unambiguous.



The Customer Requirement Worksheet

To assist you in recording Customer Voices and Images, extracting Key Items, and developing Customer Requirements, you use a simple worksheet. A small-scale example can be seen below, and a full-page version is included in Appendix F. Using this worksheet not only helps you generate requirements but provides you with an audit trail that can be useful for clarifying discussions about requirements.

The Worksheet

##	Customer Voice	Image	Key Item	Cust. Reqt

The first column is simply for the purpose of numbering the voices. The next column comes directly from the interview notes. A "Voice" is defined as an individual thought, idea, or statement that is to be considered and can be understood on its own merits. Not every word that is captured in the interview notes is transcribed here. Only the direct language that is meaningful as a unique thought from that interviewee is defined as a voice. There may be 50 or more voices from a single interview.

These guidelines will help you make good use of the requirements worksheet:

- Begin to use the worksheets early in the process.
- Leave blank rows between voices on the worksheet so you can expand the number of Key Items and Customer Requirements per voice.

Selecting Voices for Transformation

Each interview can produce dozens of customer statements (voices) appropriate for transformation into customer requirement statements. Ideally, each voice will be transformed in order to maximize the return from the exploration investment. However, on occasion this will not be feasible. In these instances there are several alternatives for selecting a subset of the total voices for review.

The preferred alternative is for every voice to be read, linked to appropriate images, and have key items determined. If the key item has been previously identified and transformed into a duplicate customer requirement statement, no further action on this voice is required.

Another alternative is for all the voices to be reviewed and categorized according to common criteria, e.g., using the Net-Touching method. The voices which are the best exemplars of each category are then selected for transformation.

Finally, another alternative is for the team to identify a list of screening factors for voice selection. For example, statements regarding regulatory requirements might be excluded if it was already known that all regulatory requirements would be met. Only the voices which passed the screening criteria would be transformed. In determining the screening factor list, it is important that each person selecting the subset of voices clearly understands the screening criteria.

Identifying the Contextual Anchor

Customer requirements must be related to the customer's actual environment. To ensure that customer requirement statements reflect the customer's experience, each selected voice is associated with an image from the Image KJ developed in step 3. The voice can be linked at any level of abstraction, i.e. first-, second-, or third-level titles, or to an actual data label; most often the linkage is made at the first-level title. It is often the case that a voice can be linked to more than one image. Creating these additional linkages is encouraged, as the new patterns of association can be a source of discovery.

Extracting the Key Item

Often it is not clear what the voice, in the context of the image, really means. Determining the key items from the marriage of the voice and image serves as a bridge to *assist* the development of the customer requirement statements. One approach to determining the key items is to start by systematically identifying significant words in the voice and making a corresponding key item. Another method is a free-association approach in which the first things that come to mind are used as the starting point. Key items are subjected to rapid iterative improvement in the requirement statement development process.

Creating the Requirement Statement

The customer requirement statement must be stated in the language of reports without being unnecessarily restrictive or ambiguous. If the requirement is clear and concise it will allow later development activities maximum design flexibility while minimizing the risk of misdirected effort.

Based on our experiences, we developed three Translation Guidelines and a Transformation Worksheet, Appendix (F). The guidelines are presented in precedence order, i.e. guideline number 1 is more important than guideline 2, and so on.

Translation Guideline 1: Avoid Statements of Means

Requirement statements that contain solutions severely restrict the freedom of designers to consider alternatives. The team should work hard, therefore, to avoid statements of means – "how to" language – when writing requirements statements.

Customer's Voice	Image	Key Item	Requirement Statement
"Quick release basket so it doesn't get in the way when moving around the boat after a fish."	"Fishing from the platform on the bow of a boat."	1. The basket is released easily.	(-) The basket has velcro fasteners. (+) The basket is releasable with one hand.

The better (+) requirement statement clearly states the requirement without restricting potential solution alternatives. The weak (-) statement restricts the solution alternatives to velcro.

Translation Guideline 2: Avoid Abstract Terms

Requirement statements which contain abstract or vague terms allow for multiple interpretations of the customer's requirement. This can result in development activities which are inconsistent with the customer's actual requirement or at cross-purposes with each other.

Customer's Voice	Image	Key Item	Requirement Statement
"Durable, material made out of cane won't last; plastic will last longer than me."	"I come home from fishing and throw my basket by the porch stairs and there it stays"	1. The basket must withstand the environment. 2. The basket must last several seasons.	(-) The basket is durable. (+) The basket is saltwater resistant. (+) The basket withstands exposure to the sun.

The better (+) requirement statements clearly state the requirements for environmental factors. In the weak (-) requirement statement, the term

"durable", permits many possible interpretations. In this project, additional requirement statements were also developed for durability as it relates to rough physical handling.

Translation Guideline 3: Use multi-valued thinking

Design constitutes a continual series of tradeoffs. Requirement statements which are multi-valued imply a range of performance and allow the developer flexibility in design. Requirement statements which are not multi-value oriented are "0/1," or "here/not-here" in orientation. Requirement statements which are written in a fashion which implies the requirement is either totally included or excluded unnecessarily restrict design freedom.

Customer's Voice	Image	Key Item	Requirement Statement
"How the water spills out of it; drainage."	"Tides, waves, seaweed"	1. drainage	(-) Water does not accumulate in the basket. (+) Water drains freely from the basket.

The better (+) requirement statement implies a performance measure (time) and range of performance (quick to slow). The weak (-) requirement statement addresses whether water does or does not accumulate in the basket.

Grammar Guidelines for Writing Requirements Effectively

Professor Shiba has taught that the subject of the requirement statement must relate to the product or its attributes. Additionally, Strunk and White's classic *The Elements of Style* identifies some principles of composition that are essential to keep in mind during requirement statement development.

"Be clear. When you say something, make sure you have said it."

Using a simple sentence structure, subject-verb-modifier helps you to be clear. For example:

> "The basket adjusts to placement on body."

Instead of:

> "The basket position can be adjusted to accommodate various casting styles. "

"Place emphatic words of a sentence at the end. The proper place in the sentence for the word or group of words that the writer desires to make most prominent is usually the end."

For example:

"Line is tangle-free."

Instead of:

"Tangle-free line is essential"

"Use the Active Voice. The active voice is more direct and vigorous than the passive."

For example:

"You can release the basket with one hand."

Instead of:

"The basket can be released with one hand."

"Put statements in positive form. Make definite assertions."

For example:

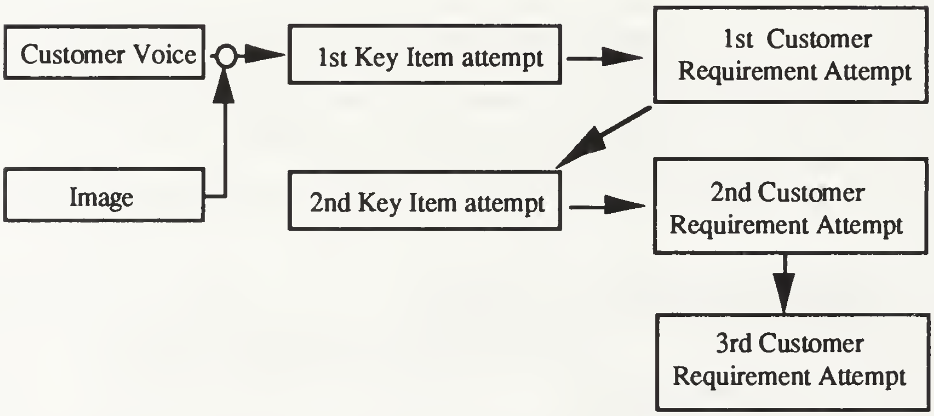
"Water drains freely,"

Instead of:

" Water does not accumulate in the basket."

Transformation Tips

- Develop the requirement statement by rapidly making successive improvement of the key items and requirement statements rather than attempting to write a statement which addresses all of the thoughts on the first try.



- Use of the word "not" is an indicator of a requirement statement which is weakness-oriented not strength-oriented. Positive-orientation is preferred as the absence of weaknesses is not strength.
- Use of the words "must" and "should" usually indicate a lack of multi-valued orientation.

- Use of the word "and" usually indicates that more than one requirement is contained in a single statement.
- It is not unusual for a single key item to produce more than one requirement statement or for multiple key items to generate only one requirement statement.
- Use of the worksheet will create a permanent audit trail that has proven very valuable in subsequent clarification discussions.
- You should block out a couple of dedicated hours for transformation work, and then leave it; come back to it at another time with a fresh perspective. Don't force it.
- Requirement statements can be developed by individuals or in small groups. We recommend that teams work in small groups (2 or 3 people) initially.
- When a group works on developing customer requirement statements together, members may find that there are different interpretations of the key items in a voice, or different interpretations of the image to which the voice relates. This may be a result of different members having heard different comments from their customer interviews or simply based on their functional backgrounds, e.g., marketing vs. engineering. Different interpretations are opportunities for creativity — for finding some hidden requirements. Pursue all of these opportunities for requirement development. You will have a chance later in the process to validate the requirement statements with customers.
- Occasionally an appropriate image cannot be located on the Image KJ. It is acceptable to use an image which did not make the final round of MPM , and is not on the Image KJ as the anchor.
- Any solutions discovered in reviewing visitation transcripts should be identified and segregated for use in Stage 4: Concept Generation.

Completion Checklist

At the completion of this step all selected voices should be transformed into Customer Requirement statements using the Translation Worksheets. Well-written requirement statements should:

- Have simple, subject-verb-modifier, sentence structure.
- Be free of specific solutions.
- Be at a concrete level of abstraction through the use of definite, specific language.

Step 5: Select Most Significant Requirements

The purpose of this step is to determine a manageable set of key customer requirements to focus on. The empathy for the customer which has been developed during prior steps is brought to bear on the selection of the most significant Customer Requirements. The Multi-stage Picking-out Method (MPM)will be used to select the most significant requirements. The requirements selected in this step will drive all further effort in Concept Engineering.

Gather Customer Requirement Statements

The final customer requirement statements which were developed in step 4 (last column of the worksheet) should be transferred onto 3"x3" "Post-It" labels and placed on a large table or wall. Due to the large number of requirement statements (300 or more is not unusual) it is useful to collocate similar requirement statements.

To initiate the collection process, the facilitator randomly picks one customer requirement statement label. It is read out loud and placed on the wall/table. Without discussion, anyone else who feels he or she has a label which is similar hands it to the facilitator, who places these labels, without reading or comment, in the vicinity of the first label. When all offered labels are posted, the facilitator randomly selects another label reads it out loud and places it on the wall or table. Again, anyone who feels he or she has a similar label will have these posted by the facilitator without comment. This continues until all labels are posted to the board. No attempt is made to formally categorize the groupings.

Define the Selection Criteria

Discuss selection criteria before conducting the MPM. It is very important that the selection criteria be focused on the *customer's* requirements, not on solutions or features which are personally attractive to members of the group. Additionally, because only the twenty to thirty most significant requirements are ultimately selected, an emphasis on diversity is important. Finally, as all labels will be reviewed and refined in Step 6, focus on the underlying thought, not necessarily the words of the requirement statement.

Select Most Significant Customer Requirement Statements

The selection process should be effective and efficient. MPM is a tool which involves everyone equally in systematically choosing a small number of items from a large number. The goal is to pick up strengths not to eliminate weaknesses. A target number of requirement statements is selected (usually around twenty-four) and a cutoff number (1/3 more than the target number) is also determined. The theme is written and displayed prominently next to the labels. The theme is usually: "What are the customer's most significant requirements for __________?" The selection criteria should also be posted next to the labels.

In the initial ("multi-dot") rounds, you can select any and all the labels you feel are significant by marking the lower right corner of the label with a marker. There is no time limit to any round or to the number of labels you can mark. However, it is important to recognize that the number must be reduced and that you have to be successively more selective. The initial rounds are completed when the number of labels remaining is approximately equal to the cutoff number.

In the final ("limited-dot") rounds, you can select only a predetermined number of labels. This limit is usually calculated by dividing the target number by the number of participants. In these rounds, you select in order. After a label is selected, it is read to the group before the next person in line selects. When everyone has selected their allotted number of labels the target number should have been reached, and the selection process is completed.

Selection Tips

- When organizing the requirement statements at the beginning of the MPM, do not title the groups; omitting titles will prevent premature classification of requirement categories.
- Emphasize that the MPM rejects are not thrown away and can be used in later development activities. This selection process is designed to select those key requirements which will define the product in the marketplace.
- Discourage discussion during the early rounds; this prevents valuable energy and time from being spent on requirement labels that will not survive the pick-up process.
- When discussion regarding the meaning of a label does occur, go back to the worksheets to ensure that the requirement statement is placed in the proper context of customer voice and image.
- During the MPM it can be useful to have someone, who is not involved in the selection process (perhaps a facilitator) separate the rejected requirement labels into groups with a common theme.

- During the final rounds of the MPM it may prove useful if the final rejects are kept handy for review during the "check for omission" stage of the Requirement KJ in Step 6.

Completion Checklist

Upon completion of this step twenty to thirty key requirements should have been selected for subsequent investigation.

Step 6: Develop Insight into Customer Requirements

This step forms the foundation for creative concept generation. Using the requirement statements selected in step 5, the essence and structure of the Customer Requirements are abstracted and examined using the KJ method. The KJ encourages the creation and examination of a myriad of requirement relationships, which facilitates the opportunity for creativity and insight.

Review Customer Requirement Statements for Clarity

This is the first point at which each requirement statement, one at a time, will be systematically reviewed by everyone. If diverse interpretations exist, the Transformation Worksheet should be reviewed to ensure consistency with the original customer's voice and image. The requirement statement should be rewritten for clarity if required. If a everyone agrees on the interpretation of the requirement statement, discussion is not necessary.

Create Relationships

Follow the KJ process as outlined in the CQM KJ manual. The theme for the KJ might be: "What are the most significant customer requirements for __________?"

Reflect

Before progressing to the next stage of Concept Engineering, reflect on what has been learned to this point. Are there any surprises or inconsistencies which might constitute opportunities for innovation? What additional information would be useful to have? What would be done differently if it could be done over again? Is there a need to go back for additional exploration before moving forward?

Tips for Requirements KJ

- In the check for omission step, after the first round of grouping, refer to the Image KJ and late-round rejects from the requirement MPM to help identify possible key omissions.
- The first round of grouping should take an hour or so if all of the plausible relationships are to be considered. Don't rush the grouping.
- The concept of taking only one step at at time up the ladder of abstraction must be enforced in the title making process.

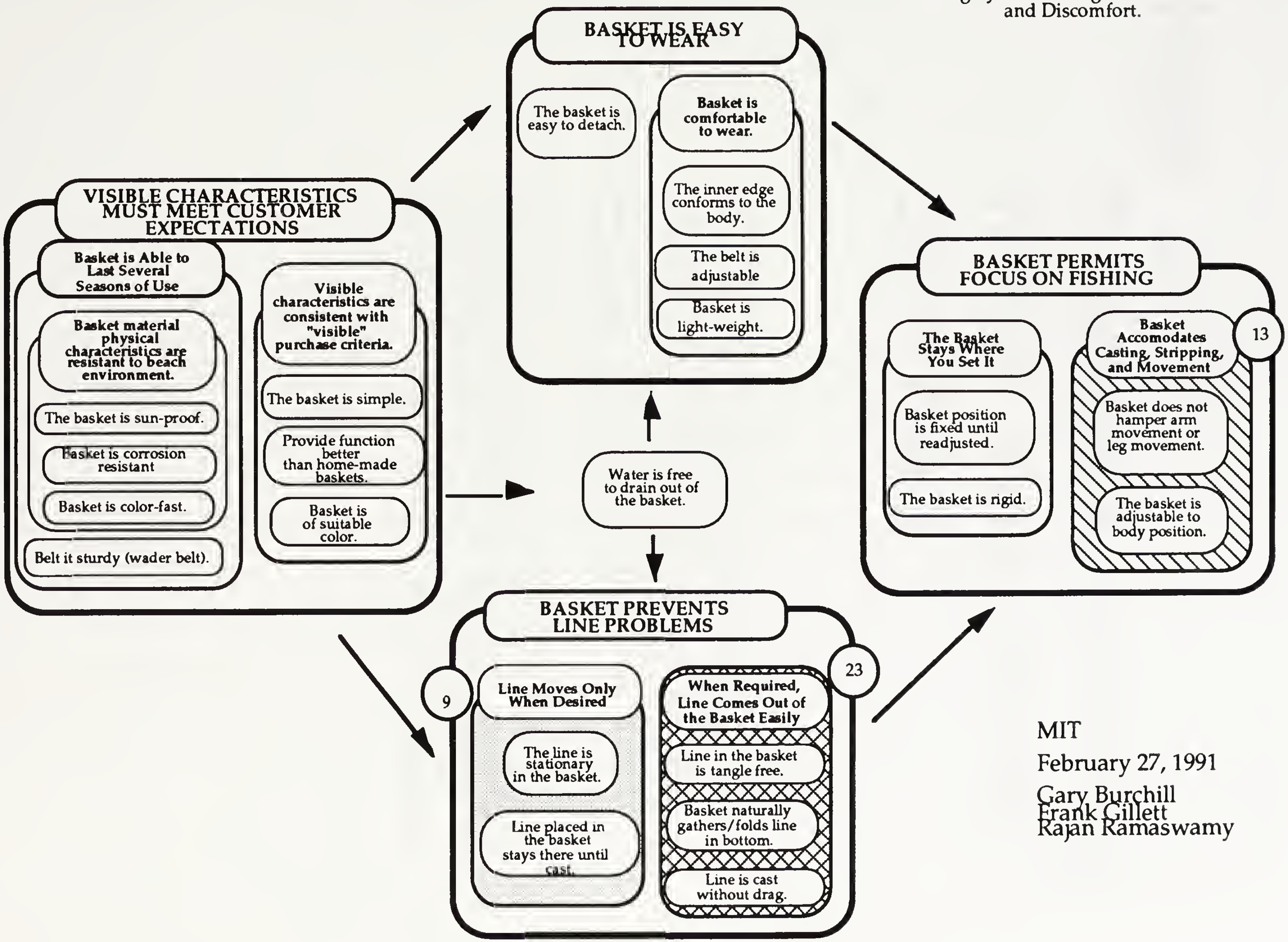
- Titles should only address the intersection, <u>not</u> the union of the labels in the group.

Completion Checklist

At the completion of this step the Customer Requirements selected in Step 5 will be structured in a Customer Requirements KJ.

What are the Customers' Requirements for a Stripping Basket?

It Should Allow You to Focus on Fishing by Eliminating Line Problems and Discomfort.

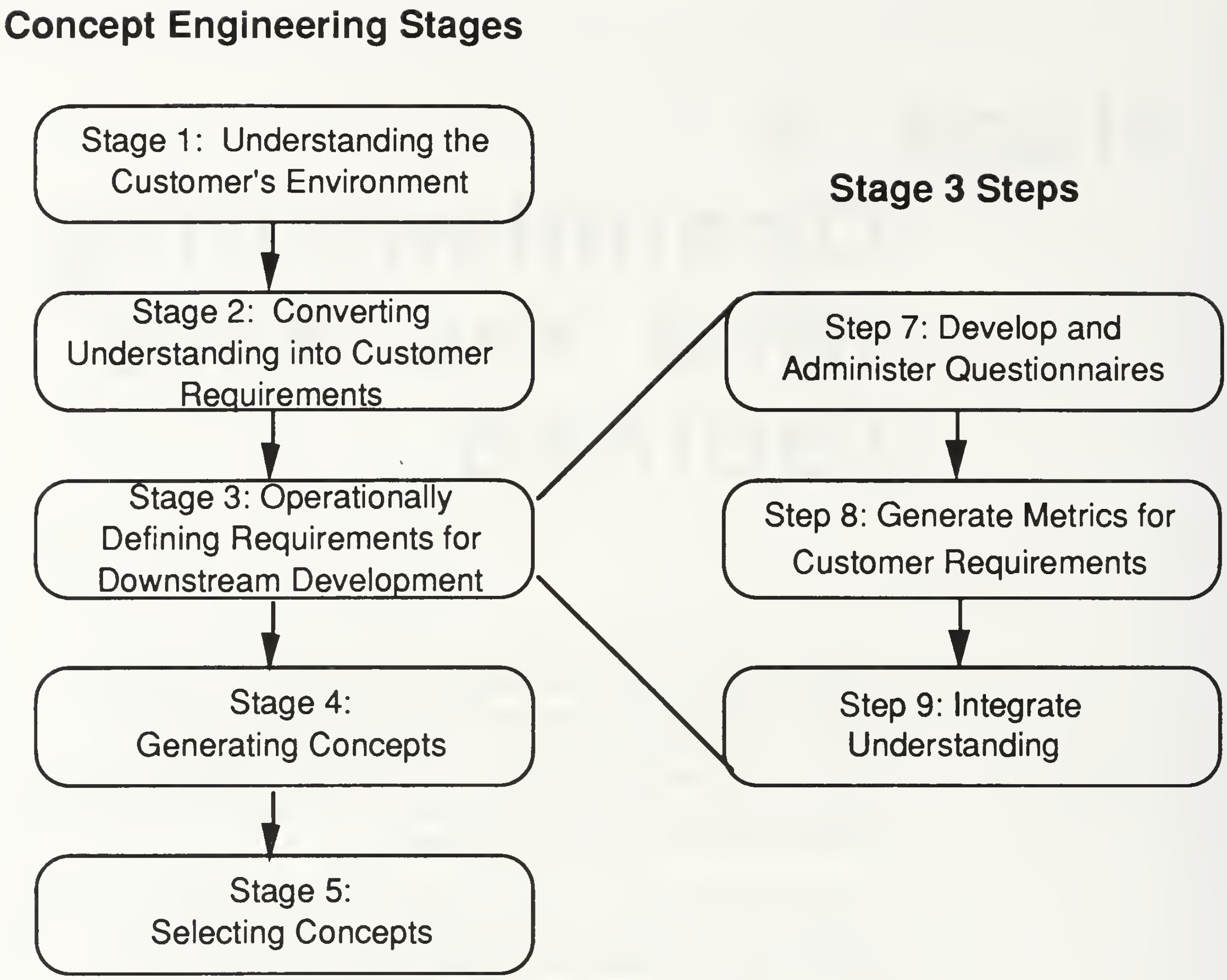


MIT
February 27, 1991
Gary Burchill
Frank Gillett
Rajan Ramaswamy

Stage 3: Operationalizing What You Have Learned

We have heard repeated complaints that development concepts changed over time, even after managers had "signed off" in various review processes. Clearly, the product development process is inefficient if people do not agree on what is important or expected. Stage 3, *Operationalizing What You Have Learned*, should ensure that the key Customer Requirements are clearly, concisely, and unambiguously stated in measurable terms.

At the completion of this stage, the team will have developed a Quality Chart and Operational Definitions. By reviewing these documents, anyone associated with the development effort can easily see the relationships between Customer Requirements and can determine their relative priority. They can also find specific measurement techniques for assessing conformance to the requirements.


Concept Engineering Stages
Stage 1: Understanding the Customer's Environment
Stage 2: Converting Understanding into Customer Requirements
Stage 3: Operationally Defining Requirements for Downstream Development
Stage 4: Generating Concepts
Stage 5: Selecting Concepts
Stage 3 Steps
Step 7: Develop and Administer Questionnaires
Step 8: Generate Metrics for Customer Requirements
Step 9: Integrate Understanding

Step 7: Develop and Administer Questionnaires

The product development team will enter Step 7 with a well-focused list of key requirements. The main objective of Step 7 is to help the design team develop a feeling for which requirements should receive the greatest attention from the team in later design efforts.

We will use three procedures to achieve this goal:

- The Kano Questionnaire, which characterizes the nature of the requirements
- The Self-stated Importance Questionnaire, which measures the importance of the requirements
- The Critical Requirement Questionnaire, which selects the critical groups of requirements.

In general, the steps to follow for all questionnaires are as follows:

1. Develop the questionnaires
2. Test the questionnaires and revise if necessary
3. Administer the questionnaires to customers
4. Process the results
5. Analyze the results

This section emphasizes the Kano Questionnaire, a tool we are just learning to use. We briefly address the other two questionnaires first.

Self-Stated Importance Questionnaire

According to research by Professor Hauser at MIT, The Self-Stated Importance Questionnaire can be helpful in understanding the relative importance of each requirement for the customers.

Method

Constructing the Self-Stated Importance Questionnaire is straight-forward:

1. For each of the requirements (the black-level labels) on the Requirement KJ, construct a question in the following general format: "*How important is it or would it be if:* [requirement x]?" For example: "How important is it or would it be if the line is cast without drag?"
2. Provide a scale on which customers can mark their responses, from "Not at All Important", to "Extremely Important."

Stripping Basket Self-Stated Importance Questionnaire

	Not at All Important		Somewhat Important		Important	Very Important		Extremely Important	
How important is it or would it be if: the line is cast without tangles?	1	2	3	4	5	6	7	8	9
How important is it or would it be if: the water drains from the basket freely?	1	2	3	4	5	6	7	8	9
How important is it or would it be if: the basket color does not fade over time?	1	2	3	4	5	6	7	8	9
How important is it or would it be if: the basket can be attached at different body positions?	1	2	3	4	5	6	7	8	9

Critical Requirements Questionnaire

As we indicated in the discussion of the Requirements KJ, we recommend having customers perform the voting step. If you wish to have customers vote on your Requirements KJ, it is convenient to gather their input at the same time you distribute the other questionnaires. Therefore, you may also want to construct a Critical Requirements Questionnaire. The only drawback is potentially overloading your customers with materials. You must make a judgement call about how much material they can handle.

Method

1. Make a list of the red-level labels (black labels that are lone wolves at the red-level belong in the list too). If you wish, you can provide additional detail by indenting the text from the black-level groups under the appropriate titles.
2. Instruct the customer to pick the 3 most important items from the red-level list and rank them in priority.

Kano Questionnaire

Professor Noriaki Kano has developed a tool which helps us understand the relationship between the fulfillment (or non-fulfillment) of a requirement and the satisfaction or dissatisfaction experienced by the customer. Kano achieves this by classifying each customer requirement into one of 5 categories: must-be, attractive, one-

dimensional, indifferent, and reverse. The definitions for these terms and a synopsis of the underlying theory are presented in Appendix D, "Understanding Kano Theory." We suggest that first-time readers review this appendix before proceeding.

The Kano Questionnaire is only one tool for setting development priorities. While it provides a unique perspective on customer requirements, it is probably most effective when interpreted as a guide to be combined with other requirement assessment methods.

Method

In constructing the questionnaire you will form two questions for each of the requirements appearing in your Requirements KJ. The first question will always refer to a situation in which the requirement is met, and will be worded in a format similar to the following: "If the [product] satisfied [requirement x], how would you feel?" This is called a *functioning* question. The second question will always refer to the case where the requirement is not met. This is called the *dysfunctioning* question, and is worded in a format similar to the following: "If the [product] did not satisfy [requirement x], how would you feel?"

Developing the Kano Questionnaire

Divide the requirements from your KJ among team members.Write a functioning and dysfunctioning question for each requirement using the guidelines below:

- You may have to step down the ladder of abstraction to construct a clear question. Avoid straying from the original intent of the customer requirement statement. Refer to the Requirement KJ and Translation Worksheets if necessary.
- Beware of polar wording in the question pairs; multi-valued orientation is preferred. Consider this functional question: "If line placed in the basket stays in it until cast, how would you feel?" instead of wording the dysfunctioning question : "If line placed in the basket falls out before casting, how would you feel?"; It would be preferable to ask, "If some line placed in the basket falls out before casting, how would you feel?"
- Don't try to cram several thoughts into one question. You want to know which question the respondent is answering. If a particular requirement contains more than one thought, use more than one Kano question. If you opt to generate more than one question for some requirements, you should keep in mind the need to keep the survey as short as possible.
- When you have functional and dysfunctional wordings for each question, put the five standard answers beside each question as follows.

Stripping Basket Kano Questionnaire

8a.If the line does not move around in the basket, how do you feel?	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it that way. .
8b.If the line moves around in the basket, how do you feel?	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it that way.
9a.If line placed in the basket stays there until casting, how do you feel?	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it that way.
9b.If some line placed in the basket comes out before casting, how do you feel?	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it that way.
10a.If line in the basket is tangle free, how do you feel?	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it that way.
10b.If line in the basket occasionally tangles, how do you feel?	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it that way.
11a.If line gathers naturally in the bottom of the basket, how do you feel?	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it that way.
11b.If line does not gather naturally in the bottom of the basket, how do you feel?	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it that way.

Testing the Questionnaires

Since the questionnaires will be sent to many customers, it's important that they be understandable. We recommend testing all of the questionnaires internally before distributing them to customers. A test

run will help identify confusing wording, typographical errors, or unclear instructions.

Refining the questionnaires may require iteration. These guidelines can help you test your questionnaires effectively:

1. Have the team answer the questionnaire first. Think of a customer and try to predict their responses. Note which questions you think your customer may not understand.
2. Select people inside your company to answer the questionnaire, and administer it to them. Select from a variety of backgrounds, e.g. senior managers, development engineers, marketing personnel, etc.
3. Revise the questions and retest.

Administering the Questionnaires

There are many details to consider in administering the questionnaires.

- Select the customers you would like to survey. We suggest returning to the customer selection matrix to develop a target list, applying the same criteria discussed in that step. In order to assure a statistically significant sample, most teams poll considerably more customers than were interviewed. Remember that not all customers will respond (for more information, see Appendix C, "Additional Hints on Administering Surveys").
- Decide on the medium to be used. You might use telephone (voice or fax), face-to-face presentation, mail, or other means. The most common method is through the mail. If you plan to use the mail, write a letter of introduction which explains the purpose of the survey and includes directions for the customer. See Appendix C for an example.
- Collect demographic data which will enable you to distinguish potential market segments if they exist. Consider collecting information on company and personal characteristics, familiarity or experience with product, use of competitors products, etc.
- Include instructions for filling out the questionnaires. This is particularly important for the Kano questionnaire since it is likely to be new to customers.
- If you are using the Self-Stated Questionnaire in addition to the Kano Questionnaire, use the same sequencing of questions to make comparing the results of the two questionnaires easier.
- Send out the surveys. Keep a log of customers to whom the surveys were sent, along with the date. This will help to avoid duplication if you choose to expand your sample later, and to follow up if necessary.
- Record responses as they arrive.

Processing the Kano Results

1. Translate each response to the question pair into a quality element code. To do so, look at each pair of questions on the Kano survey, and note the Functioning and Dysfunctioning answers for each question. Refer to the Two-dimensional table of evaluation, shown below, and locate the cell at the intersection of the Functioning and Dysfunctioning responses.

Two-dimensional table of Evaluation

		Dysfunctioning				
		1. like	2. must-be	3. neutral	4. live with	5. dislike
Funct-ioning	1. like	Q	A	A	A	O
	2. must-be	R	I	I	I	M
	3. neutral	R	I	I	I	M
	4. live with	R	I	I	I	M
	5. dislike	R	R	R	R	Q

Customer Requirement is:

A: Attractive
M: Must-be
R: Reverse
O: One-dimensional
Q: Questionable result
I: Indifferent

To illustrate how to score the questionnaire, question 9 from the stripping basket questionnaire is shown below.

9a.If line placed in the basket stays there until casting, how do you feel?	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it.
9b.If some line placed in the basket comes out before casting, how do you feel?	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it.

If the customer responded to part (a) by circling #1 "I like it that way" and responded to part (b) by circling #5 "I dislike it", then look at the intersection of the first row and the fifth column, you will find an "O," indicating that the customer views the amount of line which falls out of the basket as a One-dimensional element.

2. Record the requirement codes (i.e., A, M, O, R, Q, or I) on the tabulation matrix. An example of the tabulation matrix appears below.

3. Repeat the above steps for all the questions on the survey for each customer who returned the survey.

4. In the far right column of the tabulation matrix, assign a grade to each of the requirements. The grade should be whichever code appears most often in the responses for that requirement (i.e., it is the *mode* of the responses). See the next section and Appendix D for more sophisticated analysis of Kano results.

Evaluations of C.R. for Stripping Basket Kano Questionnaire

C.R.	A	M	O	R	Q	I	total	grade
1.	3	6	**14**				23	O
2.	5	6	**11**			1	23	O
3.	2	5	**13**			3	23	O
4.	6	1	4	1		**11**	23	I
5.	1	**9**	6	1		6	23	M
6.	**7**		2	3	1	**10**	23	I
7.	1	2	**16**		1	3	23	O
8.	2	8	**11**	2			23	O
9.		10	**13**				23	O
10.		**13**	10				23	M
11.	3	4	**14**			1	22	O
12.		**12**	11				23	M
13.	9	1	2			**11**	23	I
14.	6	2	**11**			4	23	O
15.	6	4	**11**		1		22	O
16.	1	7	**13**			2	23	O
17.	1	3	**18**				23	O
18.		5	**14**	1		3	23	O
19.		8	**15**				23	O
20.	**9**	1	8			5	23	A

Kano Response Analysis

Several benefits are obtained from analyzing Kano data:

- Gaining a better understanding of requirements

- Prioritizing requirements for development activities
- Distinguishing market segment characteristics.

In the discussion of the underlying theory, Appendix D, we addressed the qualitative distinctions between the five types of quality elements. Some screening rules were provided in the previous section. This section will focus on techniques we can use to interpret the data for prioritizing future development activities. Remember that the purpose of these questionnaires is to better understand the characteristics of the customers' requirements. The responses to these questionnaires should be seen only as a guide —no exact answer is provided as to which features must be included in the product, or which requirements need not be fully satisfied.

Alternative Analysis Approaches

A simple way to rank the requirements is to score each according to the mode, the most frequently occurring dimension in each row of the tabulation matrix. Thus, a requirement voted Must-be by 43% of respondents and Attractive by 38% of respondents would be interpreted as a Must-be requirement.

You may want to investigate the response distribution beyond the simple mode, i.e., looking at the second most frequent dimension for each requirement. For example, take a case where there are two questions and fifty responses to each. Thirty customers rate the first requirement Attractive and twenty rate it Indifferent. On the second requirement, thirty customers again rate it Attractive, but the remaining twenty rate it Must-Be. In this case, it is likely that the two requirements should be treated differently by the team. The second requirement should receive higher priority from the team.

We suggest constructing a spreadsheet with columns for the first, second, and third most frequent responses. The next step is to rearrange the rows into groups according to the following order: Must-Be's first, One-Dimensionals second, followed by Attractives, Indifferents, and Reverse requirements.

The Self-Stated Questionnaire responses can be helpful in further sorting the Kano responses. One way to order the requirements within each group is by importance ranking. For example, if there were 15 requirements whose mode was "Attractive," you might use the Self-Stated Importance data to rank the Attractive requirements in descending order of importance. This would help to further discriminate which Attractive requirements the team might want to focus on.

Interpretation

Decisions on what will be included in your product are influenced by many factors. As a general guideline, we suggest that you seek to

fulfill all Must-Be Requirements, be competitive with market leaders on the One-Dimensional Requirements, and include some differentiating Attractive elements.

In general, the return you can expect from fulfilling a requirement (in terms of customer satisfaction) should guide the effort you invest to fulfill it. Improving performance on a Must-Be Customer Requirement which is already at a satisfactory level is not productive when compared to improving performance on a One-Dimensional or Attractive Requirement. Classifying Customer Requirements into Kano's dimensions can help you to focus on the vital few where the most leverage exists.

Additionally, you should use demographic data in conjunction with questionnaire analysis to identify potentially differentiating market segment characteristics.

Continuous/Graphical Analysis Approach

The Statistics Subcommittee of the CQM Research Committee considered more sophisticated methods of questionnaire analysis. These ideas are presented in Appendix D.

Tips

- The time you are taking to hear your customers' views contributes to the company's professional image. The format of the questionnaires should further enhance that image.
- Listen carefully and without bias to what your internal test customers say. If they find something confusing, it is quite likely that others will as well. Revise questions or add instructions as necessary.
- Establishing the method by which the data will be analyzed before disseminating the questionnaires will save time. Will you use manual or automated input and analysis tools? Knowing this will enable you to marshal the necessary resources while you are waiting for replies.
- When two Kano codes are tied in the scoring for a given question, consider:
    1. Following up with customers for additional insight
    2. Looking for market segmentation differences
    3. Selecting the classification that would have the greatest impact on the product (use the following ordering: Must-be >One-dimensional >Attractive >Indifferent)
- It is helpful to get some advice from someone in your firm who has experience with customer surveys.
- A small gift to those who complete the questionnaire may improve response rate *and* generate customer satisfaction!

Completion Checklist

At the end of this step, you should have:

- Compiled and tested questionnaires
- A mailing list of respondents
- An analysis template.

STEP 8: Generate Metrics for Requirements

This step will identify the metrics which will be used to assess each Customer Requirement. You will use these metrics to objectively evaluate alternative design solutions in the Concept Selection Stage of Concept Engineering. Metrics can also be used to benchmark competitive products. Additionally, the process of generating metrics increases your understanding of requirements by requiring you to work down the ladder of abstraction.

The team will brainstorm possible metrics for each requirement and then select the smallest set of metrics (usually one or two) which cover the specific requirement. Some requirements are relatively straight-forward (e.g., "the line in the basket is tangle free when cast "). Developing a measurement unit to assess these requirements is fairly uncomplicated.

However, some requirements are more ambiguous (e.g., "the basket is comfortable"). Developing measurement units for these requirements can be difficult, in that any one measurement unit will measure only part of the requirement and in addition will also assess some other dimension. In these instances multiple metrics may be requried to assess one requirement.

At the end of this step, a tree diagram will be used to organize the set of metrics and identify any missing ones.

Method

Brainstorm Customer Requirement Metrics

Working with one Customer Requirement at a time, use traditional brainstorming techniques to generate a list of possible metrics which could be used to assess this requirement. Try to make this list collectively exhaustive; attempt to get all ideas for measuring each requirement surfaced for consideration. Develop a brief working definition for each possible metric. This definition need only be detailed enough to ensure that members of the team have consistent interpretations of the metrics' intent.

The team can split into small groups or pairs and divide up the Customer Requirements to save time. If the team is going to split up, we recommend working on one or two Customer Requirements as a full group first so that everyone gets a sense of how this is done, and then dividing the remaining requirements among teams of two or three members.

Evaluate Validity

Determine how valid each metric is; validity is the degree to which each metric actually measures the requirement, i.e., directly measures the requirement rather than measuring something else. Informal validity assessments can be made through group consensus rating of each potential metric on a high, medium, or low scale. With informal assessment, a simple thumbs up for high, thumbs across for medium and thumbs down for low vote has worked well. With this approach, select the score which receives the most votes. In the event of a tie, select the lower value, i.e., select low if there is a tie between medium and low.

Alternatively, the team could defer to the opinion of a recognized expert. Formal validity assessments also can be conducted using statistical procedures such as correlation analysis or signal-to- noise ratios.

Evaluate Feasibility

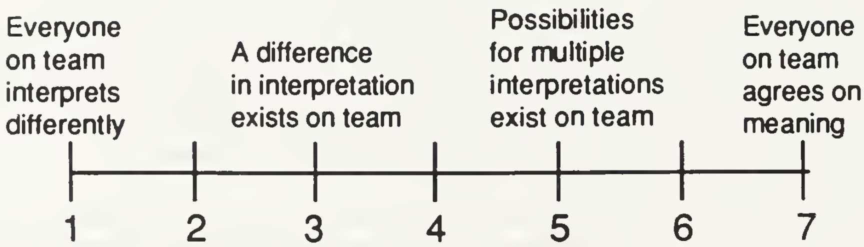
Feasibility is how easy or difficult it would be to use the metric; to actually collect and interpret the data.

Informally assess the feasibility of using each metric using a high, medium and low scale.

As a guideline in evaluating feasibility, consider briefly describing how the data would be collected (local check sheets, existing reports, etc.), and how the data would be analyzed,(e.g., personal computer spreadsheet analysis or mainframe application development). You might use this technique for every metric, or when the team has difficulty assessing feasibility or disagrees on the feasibility of a metric.

Assess Ambiguity

In order to select the smallest set of metrics, you need to assess the ambiguity of each Customer Requirement. Requirements that are ambiguous will probably need more than one metric to assess them well. Give each Customer Requirement a rating on an ambiguity scale such as the following:



Select Vital Few Metrics

For those Requirements with ambiguity ratings in the 5-7 range, select the best metric to carry forward to the next step. If you have a highly valid, highly feasible metric, then the choice is obvious. If not, use the ranking scale below.

For those Requirements with an ambiguity rating of less than 5 , you'll probably need to select more than one metric. Two or three will probably be enough to cover the requirement. Select the highest ranking metrics which seem to cover the different aspects of the requirement.

Validity	⊙	⊙	○	○	⊙	○	△	△	△
Feasibility	⊙	○	⊙	○	△	△	⊙	○	△
Rank	1	2	3	4	5	6	7	8	9

⊙ = Strong ○ = Medium △ = Weak

Repeat for each Customer Requirement

Repeat the process of generating metrics, assessing validity, feasibility and ambiguity and selecting the smallest set for each of the CRs.

Stripping Basket Example

C.R: Line is cast without tangles.

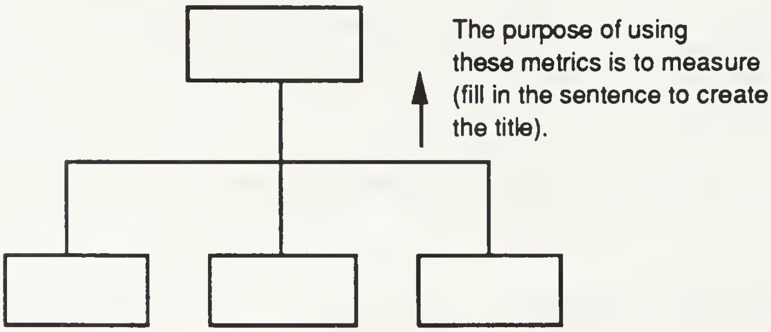
Feasibility	Validity	Measure
△	△	Count the number of perpendicular loops before cast.
△	○	Count the number of overlapping loops.
⊙	⊙	Calculate the percentage of fouled casts
* ⊙	⊙	Calculate the percentage of fouled drops.

Ambiguity assessment: 6 (everyone basically agrees on interpretation; it is straightforward). One metric is selected to carry forward to the tree diagram: Calculate the percentage of fouled drops.

Construct a Tree Diagram of the selected Metrics

A Tree Diagram is an analytical tool used for assuring a complete set of answers to a "How to" question. The Tree Diagram is often used for solution generation, as in "How do we successfully complete Project X". In this step of Concept Engineering, we use the Tree Diagram to answer the question, "How do we measure the key Customer Requirements for Product X?". This tool systematically builds a hierarchy of metrics and their purposes, and by doing so a team can then step down this hierarchy and search for missing or better metrics or groups of metrics. An example from the stripping basket is on page 3.18.

1. Prepare a Tree Diagram (CQM manual 4P) using the theme: "How are the customer's requirements measured?" Use the metrics carried forward from earlier work as the first-level labels for the tree. Leave much room on the paper for adding new metrics or groups of metrics in later steps.
2. Group each metric by common purpose. Ask, "What's the purpose of collecting this data?"
3. Write a title for each group which completes the sentence, "the purpose of using these metrics is to measure ___________."



4. Continue the process of grouping by similar purposes and writing titles until there are five or fewer groups.

Top-down checking

This stage of the Tree Diagram method is quite important, and too often teams rush through it and don't gain the benefit. It is a structured brainstorming approach to generating better metrics. Take your time and work at generating missing or better metrics.

1. Start at the top of the tree and work down one level at a time, asking, "what, if anything is missing?" For example, if after grouping was completed there were three high-level groups of metrics, check if these groups assess the full set of customer requirements or if something is missing. If you identify a missing group, write a title for that group at the proper level of abstraction

and then work down the tree, creating titles and metrics as appropriate.

2. Step down to the next level on the tree, continuing to search for omissions.
3. At the first title level, continue top-down checking, improving existing metrics or adding new ones.

Evaluating the metrics

Once the top-down checking is complete, it is time to evaluate the full set of metrics in order to identify the strongest ones.

1. Draw an evaluation table on the bottom of the tree which consists of one row each for effectiveness, feasibility, and rank, and one column for each metric.
2. Assess effectiveness of each metric. Ask, "how effective is this metric toward achieving the purpose of the title above?" You will most likely use high, medium, and low consensus ratings.
3. Assess feasibility of each metric. Either use the feasibility rating you gave the metric in the brainstorming step, or if the metric is a new one which emerged from the top-down checking, then assess the feasibility the same way you did earlier.
4. Rank the metrics using the same table used to select metrics prior to the tree diagram.

Tips

- It is highly likely that the most effective metrics are not measures which are collected and analyzed in the current information system. Therefore, don't limit brainstorming to only measures currently collected.
- If it is necessary to find stronger metrics, return to the tree diagram and look for metrics which are highly effective, but medium or low in feasibility. Think about ways to make these metrics more feasible.
- This may be a good time to bring others into the team who have more knowledge about metrics commonly used to assess customer requirements. Balance this against the time necessary to get others familiar with the requirements and the process.
- When in doubt about a particular high/medium/low assessment of validity or feasibility, err on the low side so that the strongest metrics are easier to identify.

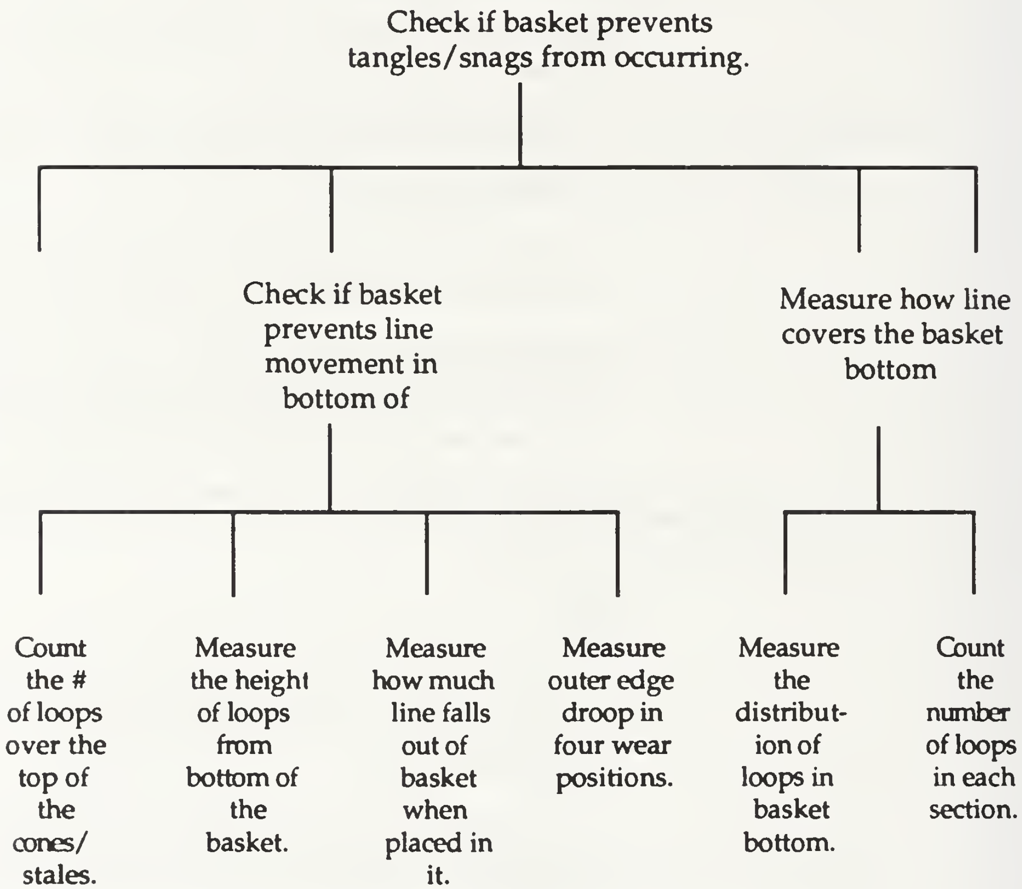
Completion checklist

At the end of this step, you should have:

- Worksheets that document metrics development

- A tree diagram of metrics that covers the full set of Customer Requirements.

Stripping Basket Tree Diagram Example



Effectiveness	⊙	△	⊙	○	⊙	⊙
Feasibility	○	⊙	○	⊙	○	⊙
Rank	2	7	2	3	2	1

STEP 9: Integrate Understanding About Customer Requirements

This step captures the knowledge gained to date in the development process about the customer's requirements and their metrics. It displays the information in a format which allows for clear, concise communication to everyone concerned. It is an important reference point for downstream development activities.

This step ends Stage 3 of Concept Engineering and in a sense finishes the work in the "requirements space." The next stage, Concept Generation, begins work in the "solution space."

Method

Prepare the Quality Chart

1. Convert the Customer Requirement KJ into a tree structure and rewrite all of the labels onto 2"x3" post-its.

1st level	2nd level	3rd level
Basket prevents line problems	The line moves only when desired	Line is stationary in basket
		Line placed in the basket stays there until cast
	When required the line comes out of the basket easily	Line in the basket is tangle free
		Basket naturally gathers line in the bottom
		Line is cast without drag

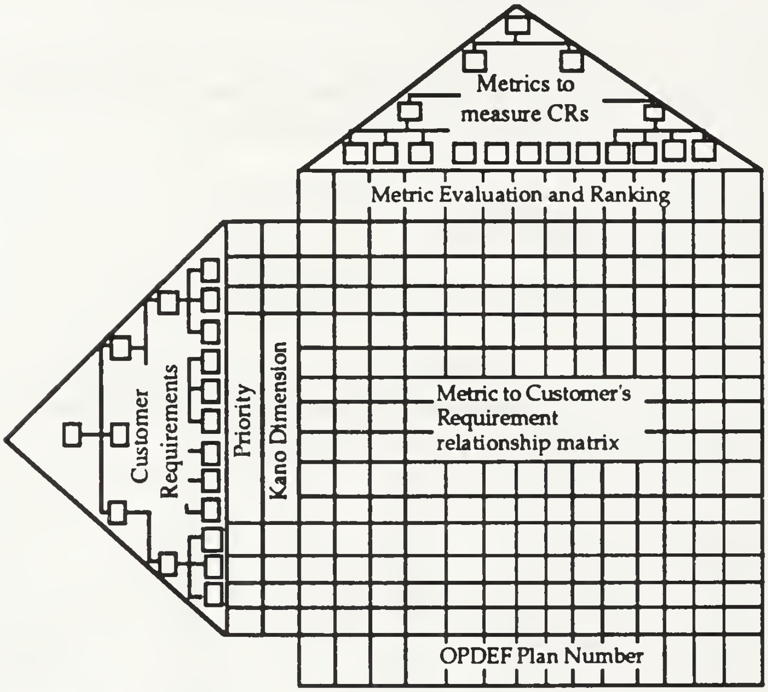
2. Place the CR Tree on the left vertical axis of the matrix.
3. Place the entire Metrics Tree Diagram on the top horizontal axis of the matrix.

4. Leave room for two columns just to the right of the requirements for the results of the importance and Kano analysis.

5. Add one row at the bottom starting, it just to the right of the two columns from Step 3, for noting the operational definition identification number.

6. Draw a grid using the lowest level labels on each axis to determine the width of the rows and columns.

Example: Quality Chart



Assess the strength of Requirement to Metric relationship

1. Start with metrics which were ranked "1" from the evaluation of the tree diagram.

2. One metric at a time, assess the correlation to each requirement. Ask, "How well is requirement _____ measured by ______ metic?"

3. Rate each metric as to how well it assesses each requirement on a high, medium, or low scale , *or* blank for no correlation. Alternatively, the team could defer to the opinion of an expert.

4. Continue with each metric which was rated a "1". Check for requirements which don't have a strong correlation to a metric (there will most likely be some). If there are requirements without a strong metric, go onto metrics rated a "2", and assess each of these against the requirements. Check again for requirements which are not covered.

5. Continue correlation assessment until all requirements have at least one strong metric or until you've assessed all metrics.
6. Formal assessments can be conducted using statistical procedures for assessing correlation or signal-to-noise ratios. This type of assessment would be time-consuming and probably best used in situations where the team feels their insight is cloudy, or the team feels the need to calibrate its intuition.

Evaluate the Matrix

Select the best set of metrics by following these guidelines:

- If there are any rows for requirements without a strong relationship to at least one metric, identify this as an area that needs further metrics generation.
- If there are any rows for ambiguous requirements without strong relationships to at least two variables, identify this as an area that needs further metrics analysis or generation.
- If there are any requirements covered by an excessive number of metrics, investigate the potential to eliminate metrics.
- If a metric is correlated with many requirements (i.e., 4 or more), this is an indication that the metric is highly abstract and it may be difficult to interpret. You'll need to break the metric into elements which relate to different requirements. You can use the operational definitions which are described next to further define the metric so that it directly measures a requirement.

Develop Operational Definitions for Selected Metrics

Operational Definitions provide detailed plans for how requirements will be assessed. Create an operational definition for each selected metric, using the following outline:

- Define the unit of measure
- Define <u>where</u> the data will be collected
- Define <u>when</u> the data will be collected
- Define <u>what</u> specifically will be observed
- Define <u>how</u> the data will be <u>collected</u>
- Define <u>how</u> the data will be <u>displayed</u>
- Define <u>who</u> is responsible for what.

Finally, test the Operational Definitions by trying to use them. It is highly likely that they will require revision after initial trial.

Example of an Operational Definition

OPERATIONAL DEFINITION FOR DROP TIME

Unit of measure: seconds
Location: landing #6 on the building E-52 fire escape

Wrap the first 30' of line (tapered end) around a tube sock and secure with two windings of duct tape.
Strip off enough line (~55') from the reel for the sock to just reach the ground when dropped off the landing.
Strip off another 10' of line from the reel.
Randomly determine the order of basket configurations to be tested.
For each configuration:

- –drop the sock over the side;
- –strip the line into the basket without looking;
- –before dropping the sock, look in the basket and assess:
- –the ~distribution of line in the bottom of the basket;
- –the ~% of line above the top of the cones; and
- –the ~number of perpendicular loops;

Have the timer drop the sock, starting the stop watch when they let go and stopping the time when the sock strikes the bottom;
Record the time it took for the sock to drop as well as any observations regarding line payout, such as tangles, excess line payout, or others, on the attached check sheet.
Repeat the process four times for each configuration.

Reflect

This is an important time for the team to stop and reflect. You've come a long way since Step 1, Plan for Exploration. Think about what you've done and what you've learned. What insight has been gained? What surprises did you discover? What additional information do you need? What would you do differently next time?

Tips

- Don't stretch the correlation analysis. There should be *many blank cells* (indicating no correlation) on the Quality Chart.
- It may not be possible to cover every requirement with a highly correlated metric; do the best you can. If the requirement is one of critical importance, additional effort at developing a highly valid metric may be necessary.
- Quality Charts can be huge, unwieldy wall charts. One way to make the chart more manageable is to rewrite the Customer Requirements KJ and Metrics tree diagram labels onto onto 2"x3" post-its with the 2" side up against the axis for the correlation assessment. It will make the chart easier to work with.

- The Quality Chart can be used as the basis for conducting competitive Benchmarking

Completion Checklist

At the completion of this step you should have:

- A Quality Chart which includes the Customer Requirements, metrics and correlation assessment
- Operational Definitions for selected metrics.

Stage 4: Generating Concepts

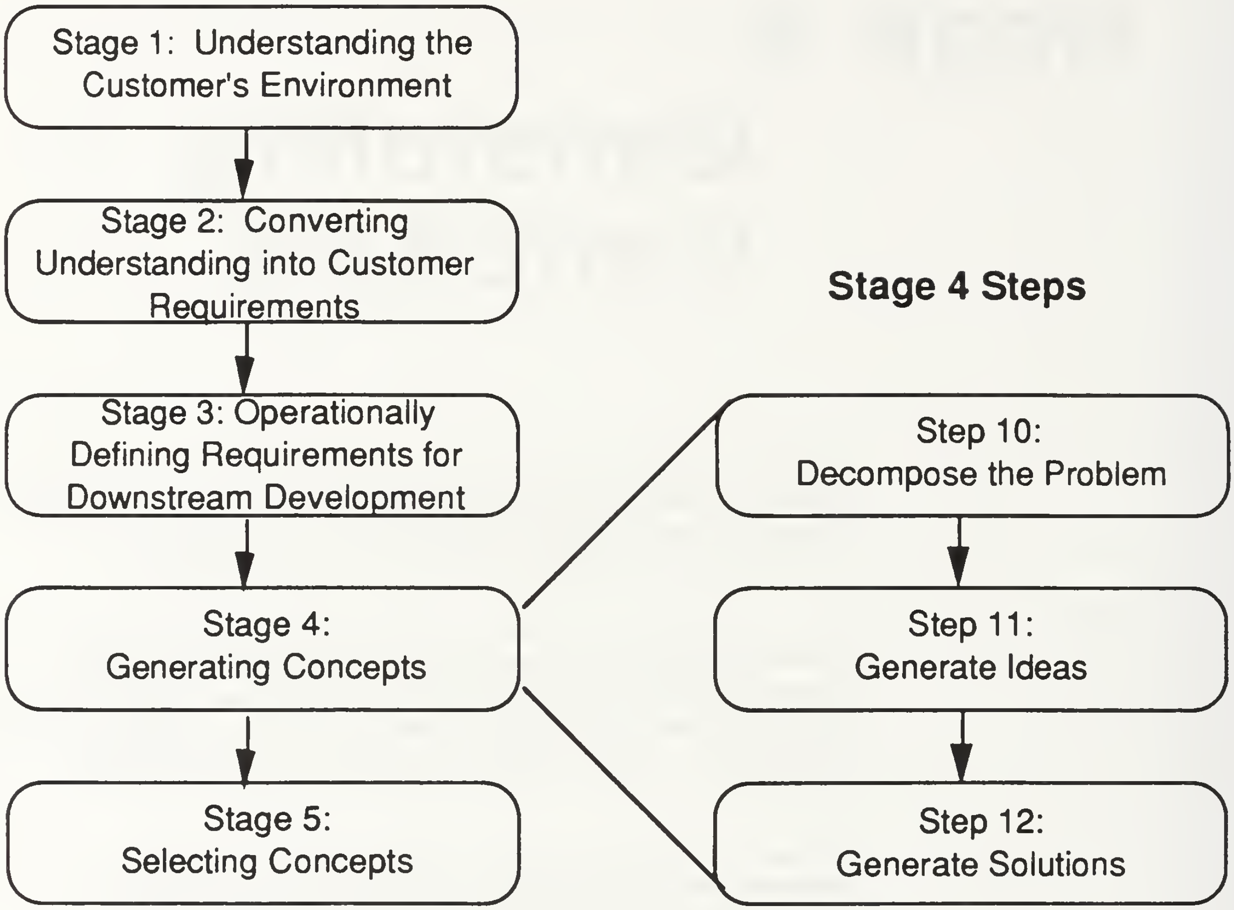
This stage marks the transition in the development team's thinking from the "requirement or problem space" to the "solution space." This is the stage of Concept Engineering that many development teams describe as the opportunity to "finally have some real fun."

Many of us have been trained to arrive at solutions as quickly as possible; good job performance has been, somewhat erroneously, equated with quick fixes. Conversely, the first three stages of Concept Engineering teach the virtue of patience as applied to product development: accurately define requirements *before* generating solutions.

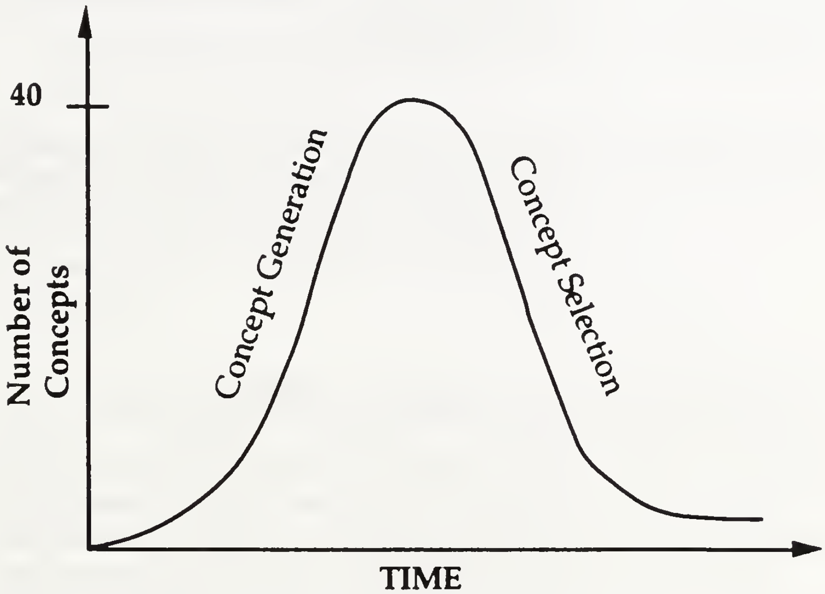
In Stage 4, the same disciplined thinking process is applied to generating potential solutions. The team will systematically decompose the development objectives and then cycle between independent and group activities to generate and identify the strongest solutions.

The self-documenting nature of Concept Engineering is maintained throughout Stage 4, where ideas and combinations of ideas are completely preserved for reflection and later review if necessary.

Concept Engineering Stages



In Stage 4 it is desirable to quickly generate many diverse concepts. In Stage 5 you will rapidly focus on the most promising solutions and converge on the dominant ones. This process is illustrated in the figure below.



Stage 4, *Generating Concepts*, comprises three general steps, as described below.

Step 10, Decompose the Problem, sets out to reduce the complexity of the problem by breaking it down into more easily handled subproblems. Many different types of decompositions of the same design problem are encouraged, to facilitate better coverage of the potential design space. Decomposition also allows for individuals or groups to work in parallel to develop solution ideas for different components of the product or system.

During Step 11, Generate Ideas, ideas are rapidly and exhaustively brainstormed and improved for each of the subproblems. Simultaneously, a search for existing solutions is also conducted in order to assure complete coverage of the solution space. Lastly, the most promising ideas are picked up by group consensus.

Step 12, Generate Solutions, begins with an exhaustive enumeration of solution combinations (combinations of solutions to each of the subproblems) followed by a rapid enhancement of the best solutions. The solution enhancement is accomplished primarily by the group's collective intuition, perhaps aided by some laboratory testing or experiments. The output is a set of plausible concepts (solution combinations) which serve as input to Stage 5, Concept Selection.

Step 10: Decompose Design Problems

The purpose of this step is to divide the complex design problem into smaller, but independent, subproblems. Multiple diverse decompositions are encouraged as an aid for enhancing coverage of the potential solution space. You can deepen and broaden your insight from the generation of ideas if the design problem is decomposed in diverse ways.

Development Objective

The first step in decomposing the design problem is to state the Development Objective. The Development Objective defines the direction of your design efforts. It is a clear, concise articulation of the requirements which focuses concept generation.

Often it is adequate to use the title or the conclusion from the Customer Requirements KJ to serve as the basis of the Development Objective. For example, the stripping basket Customer Requirements KJ conclusion reads: "It should Allow You to Focus on Fishing by Eliminating Line Problems and Discomfort." A translation of the conclusion to a Development Objective is: "The Stripping Basket must allow the customer to focus on fishing by eliminating line problems and discomfort."

Write your development objective on a flip-chart paper and hang it conspicuously on a wall to remind the team of this focal point.

Decomposition

Decompose the problem into its subcomponents. You can dothis in many ways. We recommend trying 3 or 4 decomposition possibilities and documenting them on flip-chart paper. Start with your organization's traditional development decomposition first, that is, how you would normally split up the design task. Examples of possible decompositions follow:

- Decompose by technical disciplines (mechanical, electrical,etc.) or functional components (e.g., inputs, processors, outputs).

- Customer Requirements KJ. Decomposing using customer requirements provides a customer-oriented perspective. Decomposition by first- and second-level titles is recommended.
- Metrics Tree Diagram. Decomposition by metrics from the Tree Diagram provides a technical perspective. Decomposition by first- and second-level titles is recommended.
- A process flow describes the sequence of actions involved before, during, and after the use of the product or service.

Select a minimum of two decompositions for futher development. One will usually be your traditional approach and the other should be more customer-oriented.

Coupling

Coupling allows you to identify problem areas which are independent of each other, in which solutions in one area do not effect solutions in another area. When the development team judges that the solution ideas of two (or more) decomposed subproblems overlap, those problems may be linked, or coupled, together. For example, in the stripping basket the line tangling and line drag subproblems are not independent; one is connected to the other. These requirements can be coupled together and solutions can be generated for both subproblems at the same time.

Examples of the Stripping Basket decomposition style are provided below. You will notice in the examples which follow that "coupled" subproblems are separated by heavy bold lines from the adjacent subproblem.

The decomposition format lists the subproblem as the column heading and space below in which to eventually add the brainstormed ideas for solutions(Step 11). Use large format flip-chart paper to document your decompositions. You'll use the same sheets for Step 11, Idea Generation.

The first example of coupling is the Stripping basket Customer Requirements KJ diagram. This example shows that the next higher level title is included in the table to promote clarity to the team.

Basket prevents line problems		
The line moves only when desired.	When required, line comes out of the basket easily.	Basket accommodates casting, stripping, and movement.

Stripping basket Metrics Tree Diagram. This example shows that the next higher level title is included in the table to promote clarity to the team.

Check if basket prevents tangles/snags.		
Check if basket prevents line movement in bottom	Check if line falls naturally into bottom	Check if basket prevents tangling

Problem Decomposition Example — Stripping Basket Process Flow.

Attaching basket to wearer	Stripping line into the basket	Casting line from the basket	Detaching the basket from the wearer

Tips

- Work from the Quality Chart developed in Step 9 when developing the customer-oriented decompositions.
- Stick with it. You may have difficulty with decomposition; good decoupling will pay off later when it will be easier to combine solutions from different subproblems.
- Don't be concerned if your team finds that the decomposition by functional breakdown or by process flow doesn't allow for coupling of subproblems — couples may not exist!
- Before moving forward to Step 11, post the Problem Statement sheet on a conspicuous wall to remind the development team of the task at hand.
- In order to leave adequate room for the activities of Step 11, use one sheet of paper per subproblem or coupled subproblem. Don't be alarmed at the stack of flip-chart sheets your team will generate during Step 10!

Completion Checklist

- A clearly articulated Development Objective
- At least two development decompostitions
- Decomposed, independent, subproblems written on large sheets of paper.

Step 11: Generate Ideas

Step 11 forms the bridge between the requirements space of the previous steps and the solutions space. Ideas are brainstormed for solutions to the subproblems and are combined with existing concepts found through researching literature and talking with experts and customers. This process should generate an extensive, nearly exhaustive list of possible solutions to consider.

Researching Old Concepts

In order to identify existing solutions, consider the following resources:

- Expert analysis
- Database searches
- Competitive benchmarking
- Solutions gleaned from your customer interviews.

Expert analysis may be provided by consultants, universities, R & D laboratories and your customers. Database resources, such as patent searches, on-line periodicals and trade or industry associations may produce valuable ideas. You can gain insight by evaluating the "Best In Class" or "Best In Industry" products.

You may choose to split the team up into individuals or pairs to do this research. For example, one pair could travel to the library to conduct a patent search, another could identify and interview industry experts, and still another could identify potential competitive products for subsequent team evaluation.

The results of your research must be clearly documented and assembled as a part of the project documentation.

Generating New Concepts

The generation of new ideas is a process of unconstrained thinking followed by structured reflection. The unconstrained thinking expands the boundaries of ideas for evaluation; the structured reflection focuses on picking up the strengths and opportunities contained in each idea. Initial ideas are seldom the best; push yourself and the team to create extensions and hybrids of these early ideas.

Expand feasible design space

Individually, or in a small group, create an exhaustive list of solution ideas focusing on one subproblem at a time.

For each subproblem identified in Step 10, brainstorm ideas which expand the boundaries of ordinary idea generation. For example, for each subproblem, offer ideas which test:

- Market constraints. Propose ideas that will flop in the marketplace.
- Technology constraints. Propose ideas achievable only with alchemy.
- Organizational constraints. Propose ideas likely to get you fired.

Rapidly generate feasible solution ideas which will cover the expanded solution space.

- During this independent generation of ideas, members should view the subproblems from each of the product's stakeholder perspectives: end-user, dealer, salesperson, installer, etc.
- Solution ideas do not have to be at a specific level of abstraction; any idea can contain strengths which can serve as a springboard to an even stronger idea.
- Record each idea on a 3"x3" Post-It and place on the Subproblem decomposition worksheet prepared in Step 10.

A portion of an "Idea Generation" sheet for the Stripping Basket subproblem "Line moves only when desired" is shown on the next page.

Group collaboration

Meet as a team and:

- Logically classify and group the previously generated ideas, writing titles for each group. This is similar to the Net-Touching process outlined on page 1-10.
- Review the independent idea generation results, focusing on enhancing the strength of the brainstormed ideas, <u>not</u> identifying their weaknesses. For each idea listed, ask "what are the strengths associated with this idea?" New ideas are added to the list as developed.
- Have another session (10 minutes) of independent idea generation; *push* team members to identify additional ideas. Ideas are posted to the sheet on 3"x3" Post-Its.
- Review the new ideas with a focus on enhancing their strengths. For each idea listed, ask "what are the strengths associated with this idea?" New ideas are added to the list as developed.

- Quickly assess the feasibility of the posted ideas.
- Select the most promising feasible ideas for each subproblem for further development.

Several methods for selecting the most promising ideas have been used:

- MPM, after discussing the strengths of each idea, to select the best three to five ideas. (Some teams go straight to final round selection, giving each member only one vote.)
- Apply DeBono's PMI process. PMI is an attention directing tool. Frst note the positive or Plus aspects of an idea, then note the Minus and then note the Interesting points of an idea over a period of about 2-3 minutes. A PMI worksheet can be found in Appendix (F).
- An intuitive or consensus decision process by the team.

Stripping Basket Idea Generation Examples

Line moves only when desired
Ideas which would flop • flat smooth bottom • plain flexible bottom **Ideas achievable only with alchemy** • electrostatically charged line • magnetically charged line **Ideas sure to get me fired** • spinning reel(real fly fishermen don't use spinning reels) **Other ideas** • astro turf • monofilament stakes • monofiliment loops • one traffic cone • nails • duct tape

Tips

- Start idea generation with the customer-oriented decomposition first. Complete your traditional decomposition after all alternative views have been explored.
- Suzzane Merrit of Polaroid's Creativity Lab suggests the use of a "Mental Excursion" as one method for generating additional ideas. Use the Image KJ to take a "trip" into the customer's world while concentrating on a subproblem.
- Setting specific time limits for idea generation can help concentration.
- Plan on several cycles of individual generation and group collaboration. Planning several short sessions per week has proven useful for some teams.
- Schedule a day for the team to absorb the results of the research on old concepts. The presentations from the research should become part of the project documentation.
- The first attempts at generating ideas through brainstorming can be carried out as a team activity. After the team gets the hang of brainstorming in this fashion, subproblems may be allocated to individuals or pairs.
- Personal criticism and competition should be strongly discouraged.
- Do not forget to add the ideas you uncovered in your customer visits to the list of ideas for evaluation.

Completion Checklist

- Subproblems and lists of possible solutions are documented on sheets of large chart paper; the most promising ideas are highlighted.
- Notes on research of existing concepts.

Step 12: Generate Solutions

This is the final step in Concept Generation and it is characterized by creativity and reflection as you identify the strongest solution concepts from the many ideas generated. Rapid and exhaustive linkages, combining ideas from different columns, are made to create solution concepts. The use of the summary table maintains the self-documenting nature of Concept Engineering by providing an audit trail of the range of ideas and idea combinations generated. The strongest solution concepts are carried into Stage 5 for more detailed analysis.

Create a Summary Table for Each Decomposition Style

1. Collect each of the sheets of chart paper containing subproblems and their group-selected solutions. Keep them in their decomposition groups.
2. Within a decomposition group, tape the sheets together side-by-side, creating one long document. For example, if you decomposed using three methods, you will now generate three summary tables.

Create Solution Concepts

1. Considering only one summary table (and therefore one decomposition approach) at a time, link together subproblem solutions into a total concept. In other words, select items from each column and combine them to create a solution concept.
2. Ideally, create as many alternative combinations as possible, thereby providing an opportunity for insight and learning. An alternative would be for each team member individually to create the solution concept they feel is strongest.
3. Document solution concepts by recording each combination of subproblem solutions you generate on a Concept Description Sheet–a description of the solution concept in one page or less .

Select the Strongest Solution Concepts

Review each Solution Concept individually. Eliminate those that are apparently infeasible or can readily be discounted by group consensus. However, expert evaluation and laboratory testing may be required in order to judge the relative strength of many of the other combinations. Therefore, the end point of Step 12 and the start point of Step 13 is defined as the need for the development team to use resources beyond its

own intuition in order to accomplish the convergence on the best solution concepts.

Tips

- You'll need long walls in order to accommodate the summary tables; plan to use appropriately large facilities for Step 12.
- When creating solution concepts don't be too critical; focus on generating many solution concepts.

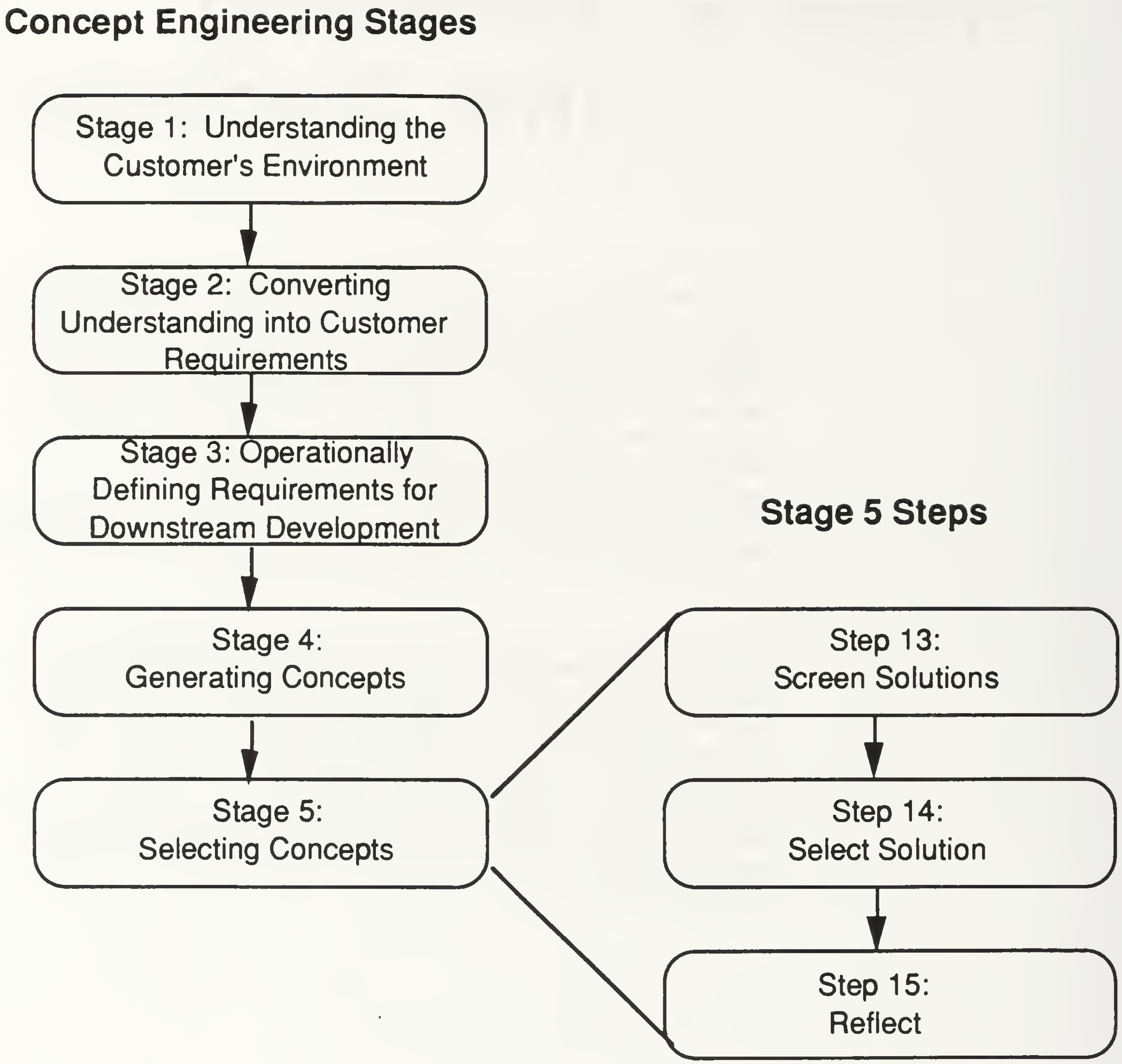
Completion Checklist

- Summary tables for each decomposition method.
- Concept Description sheets for each concept to be carried forward to Stage 5, Concept Selection.
- Concept Description sheets for each eliminated concept (save these to maintain the completeness of the project documentation package).

Stage 5: Selecting the Concept

In this final stage of Concept Engineering, a product concept is selected. In the previous stage, the development team generated a wide array of solutions to collectively address the set of Customer Requirements. In this stage, the solutions act as raw material to be refined, combined, and evaluated in an iterative fashion until a small number of complete, superior solutions remain. The best concepts are subjected to a final evaluation, combining numerical scoring algorithms with the considerable intuition built by the development team during its efforts. Selection of the dominant concepts consistent with market requirements, company capabilities, and company philosophy will be the final result of this step.

In Step 13, Screen Solutions, the team will think individually and together, seek expert help, and experiment in the laboratory in an iterative process of combining and improving initial solution concepts to develop a small number of superior concepts. In Step 14, Select the Solution, the "surviving" complete concepts are evaluated in detail, using returned Kano and Importance rating data. Two separate numerical algorithms can be used to generate scores for each concept. In Step 15, Reflect on the Process, the numerical "scores" of the concepts are considered in conjunction with other decision factors, to select the dominant concepts.


Concept Engineering Stages
Stage 1: Understanding the Customer's Environment
Stage 2: Converting Understanding into Customer Requirements
Stage 3: Operationally Defining Requirements for Downstream Development
Stage 4: Generating Concepts
Stage 5: Selecting Concepts
Stage 5 Steps
Step 13: Screen Solutions
Step 14: Select Solution
Step 15: Reflect

Step 13: Screen Solutions

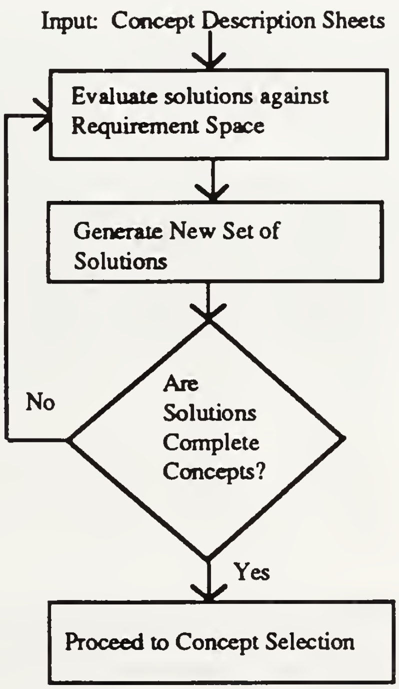
Prior to this step, the team has developed a large number of informally screened solutions which have been documented on Concept Description sheets. The task of this step is to screen, combine, and improve this set of solutions until the best elements have been fused into a small number of complete concepts. The tools at hand for this task are:

- Creative brainpower
- Experimental work
- A Concept Screening Matrix.

At the completion of this step, the remaining mature concepts will be ready for final evaluation, to be handled in the next step, Concept Selection.

Screening Process

The screening process is best explained with the help of a simple flow chart.



The initial input is the set of selected Concept Description Sheets from Step 12, Solution Generation. Some initial solutions may be incomplete, addressing only a fraction of requirement space. As iterations of this

process are completed, these solutions will address an increasingly larger fraction of requirement space. (The Concept Description Sheets must be updated accordingly.) Eventually, there will be only a few concepts remaining, but these will be complete solutions addressing all of the requirement space. When these completed concepts are optimized to the satisfaction of the team, Solution Screening is complete, and Solution Selection, Step 14 , may begin.

Evaluate Solutions against Requirement Space

The term Requirement Space is useful because it suggests the image of a map containing the set of customer requirements, along with their quality dimension and relative importance. To improve a set of partial solutions, there must be some way to evaluate them against this map.

Screening Matrix

One way to perform such an evaluation is by evaluating each solution (Concept Description) against the set of Customer Requirements generated from the Requirements KJ. The resulting screening matrix looks something like:

------------ Solutions ----------------

	A	B	C	D	E	F	G	H	I	J (Reference)
C.R. 1	+1	+2	0	N/A	N/A	+1	0	+1	-2	-1
C.R. 2	0	+1	N/A	0	+1	0	+2	-1	0	0
C.R. 3	+2	0	+1	0	-1	+2	+1	N/A	0	+1
C.R. 4	-1	N/A	N/A	+2	-1	-1	+1	-2	N/A	+1
C.R. 5	N/A	+1	+1	-1	0	N/A	N/A	N/A	+2	-2
C.R. 6	N/A	+2	0	0	0	-1	-2	+1	+2	-1
C.R. 7	N/A	N/A	0	+1	-1	+2	-1	0	+1	N/A

The solutions are arrayed along the horizontal axis and the Customer Requirements are arrayed along the vertical axis. Each cell contains an evaluation of how well a particular solution satisfies a given Customer Requirement.

Reference Concept

Because the numerical ratings in the screening matrix are relative, there must be some reference to compare against. Select a reference product. A natural selection might be your current product or a competitor's product that you deem "best in class." You can either assign the rating 0 to each facet of your reference selection or you can evaluate your reference selection, treating 0 as 'neither a market advantage nor a market disadvantage'. In either case, evaluate your solutions in reference to the rating you gave to your reference concept.

Rating Scale

The example shows evaluations including -2, -1, 0, 1, 2 and N/A. The higher ratings (1 and 2) reflect superior performance, 0 reflects some chosen reference performance, and -2 and -1 reflect sub-reference performance. Some teams find the use of -, 0, + provides sufficient information about relative performance. The N/A stands for not addressed, which simply means that the solution is not complete and does not account for that requirement. As more iterations occur, the number of N/As in the screening matrix will decrease, and the final concepts at the end of Solution Screening should address all requirements.

Alternative Screening Matrix

The Solution vs. Customer Requirements screening matrix is not the only useful screening matrix. To make judgments about how well customer requirements are satisfied by a solution can be difficult because it's hard to measure customer requirements directly.

The set of Metrics generated by the team to measure customer requirements can be easier to use to assess the solution concepts. The complete set of metrics should cover the same requirement space as the Requirement KJ. Therefore, it should be as valid to compare solutions against metrics from the Metric Tree Diagram as it is to compare solutions against requirements with an alternative screening matrix like the following one.

	Solutions									
	A	B	C	D	E	F	G	H	I	J Reference
Metric 1	+1	+2	0	N/A	N/A	+1	0	+1	-2	-1
Metric 2	0	+1	N/A	0	+1	0	+2	-1	0	0
Metric 3	+2	0	+1	0	-1	+2	+1	N/A	0	+1
Metric 4	-1	N/A	N/A	+2	-1	-1	+1	-2	N/A	+1
Metric 5	N/A	+1	+1	-1	0	N/A	N/A	N/A	+2	-2
Metric 6	N/A	+2	0	0	0	-1	-2	+1	+2	-1
Metric 7	N/A	N/A	0	+1	-1	+2	-1	0	+1	N/A

An added advantage with metrics is that you may be able to conduct relatively quick and simple experiments to determine solutions' effectiveness.

You can use either or both screening methods. Keep in mind that these tools are decision aids: use the approach most appropriate to your situation.

Completing the Screening Matrix

Completing the Screening Matrix may involve experimentation. The ratings for some cells may be easy to learn or already known. Others, however, may require physical modification of devices, quick and dirty prototype mockups, or computer modeling. The idea here is not to jump full speed into development, but to do just enough lab work to ascertain the feasibility and performance of particular solutions (a large number of mini-development cycles).

Generate New Solution Concepts

After evaluating solutions against the requirement space, you may discover that your solutions do a good job in some areas and not in others. Create new solution concepts by combining the strengths of different existing solutions.

After completing your first Screening Matrix, talk about each solution in turn with the entire group. Discuss the merits and drawbacks of each solution. Talk about possible ways to improve solutions and, wherever possible, consider combining positive elements from multiple solutions

into a single solution. Document the new Solution Concepts and complete another Screening Matrix.

After discussion, private thought, evaluation and experimentation, ideas have been refined and combined to create a new set of solutions. If the team is satisfied that the concepts are complete and there is little to be gained by further iterations, proceed to Step 14, Solution Selection. Otherwise, take your updated solution set and go through another cycle of solution generation and screening.

Tips

- Alternate group discussion with individual time for reflection.
- For early screening iterations, the -2,-1,0,1,2 scale may be more resolution than is necessary. If you'd rather distinguish only -, neutral, and + for early cycles, feel free to do so. However, for later iterations, where you are busy fine-tuning the concept, the added resolution will be very helpful.
- Reference concepts are more difficult to generate for completely new products. If there is nothing in existence that does what you want to do, try to find a set of different products that between them meet your customer requirements. Your reference concept will be a hybrid of aspects from several products.
- Don't worry if your questionnaires aren't back before you begin solution screening. They are unimportant in the early iterations, increasingly helpful in later iterations, and absolutely essential in Solution Selection. As your concepts become more complete, it becomes more important to consider the Kano dimension and the relative importance weighting of your requirements. These distinctions will significantly influence the solution "scores" in the next step.
- Feel free to add new solution ideas as inspiration strikes. If they are appropriate, they will survive the improvement cycles to follow. If not, no harm done.
- Some teams have found screening with Metrics to be easier than screening with Requirements, because metrics are inherently quantitative.
- Make sure group discussions of solutions are frequent. There are several benefits. Updated solutions will converge to completed concepts faster if everyone develops an intuitive feeling for the direction other team members are heading, and can think about solution interaction. With frequent communication, you increase the tendency for the entire team to reach intuitive consensus on final concepts.

- You may find it helpful to add organizational requirements to the screening matrix. For example, resource availability, time, manufacturing capability, technological risk, etc., could be useful criteria for screening concepts.

Completion Checklist

At the end of this step, complete solutions, which address the entire requirement space (customer requirements or metrics), should be documented on Concept Description Sheets.

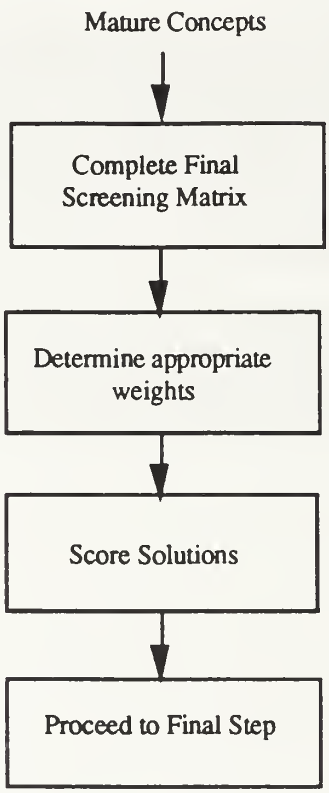
Step 14: Select the Solution

Solution Selection is a detailed numerical analysis and scoring of the mature concepts developed during Solution Screening. You will use the results of these analyses in selecting a product concepts. The basic premise of evaluating solutions against the requirement space is the same as in the previous step. However, this final numerical analysis explicitly accounts for the results of Kano data and Self-stated Importance ratings. *This scoring takes into account that some requirements are more important than others.*

As in solution screening, two separate Selection matrices are presented, one based on customer requirements, the other based on metrics. One or both of these matrices may be used to give the team a final detailed numerical evaluation of their concepts.

Process for Selection

Here is the process flow for Solution Selection:



Once again, you may choose to assess your solution concepts against Customer Requirements or Metrics or both. The Metric algorithm, as before, has the advantage of being directly measurable. However, the Requirement algorithm is easily adaptable to Kano data. Each will be described and an example shown.

Requirement-Based Scoring

This scoring method can consider the importance weights and/or the Kano results for the set of Customer Requirements.

Screening Matrix Without Kano Results

Begin with the screening matrix, Customer Requirements against Solutions, (cell-performance ratings are -2,-1,0,1, and 2 as in the previous step), with an extra column for Self-Stated Importance Questionnaire data.

	Self-Stated Importance Ratings	Solutions A	B	C	D
C.R. 1	1	+2	+1	0	+1
C.R. 2	2	0	+1	-2	+2
C.R. 3	4	+1	0	+2	+1
C.R. 4	3	-1	+1	+2	0
Solution Scores		3	6	12	9

Scoring Without Kano

If we included Importance Ratings and not Kano data, we would calculate solution scores as the sum of performance ratings, weighted by the corresponding Self-Stated Importance Ratings. Solution A, for example, would have a score of (+2)(1) + (0)(2) + (+1)(4) + (-1)(3) = 3. Those solutions with the highest scores would dominate.

Screening Matrix Including Kano results:

To account for Kano results, we must redefine the cell performance ratings. For example, if a given requirement has purely attractive quality (A) and it is implemented well, customers are very satisfied; if implemented poorly or not at all, customers don't care. Suppose we had a solution which scored a -2 (very poor implementation) for this requirement. With our existing scoring method, the -2 rating would detract from the overall effectiveness score for the concept. However, we know for Attractive quality, a poor score has no effect on how a product is perceived. Thus, the -2 rating for Attractive quality should be changed to a 0 rating. Continuing this line of thinking, the various Kano results should be redefined as follows:

	A	O	M	I
Old	-2 -1 0 1 2	-2 -1 0 1 2	-2 -1 0 1 2	-2 -1 0 1 2
New	0 0 0 1 2	-2 -1 0 1 2	-2 -1 0 0 0	0 0 0 0 0

Here is a Screening Matrix with Kano data included:

	Kano Dimension	Self-Stated Importance Ratings	A	B	C	D
C.R. 1	M :60 O:40	1	+2	+1	0	+1
C.R. 2	O:100	2	0	+1	-2	+2
C.R. 3	A:50 O:50	4	+1	0	+2	+1
C.R. 4	M:60 I:40	3	-1	+1	+2	0
Solution Scores						

(Columns A–D: - - - - - Solutions - - - - -)

In this example, 100 people responded to Kano surveys and the team considered the top two Kano scores versus just the mode response. Using our new ratings, accounting for Kano Dimensions, a scoring example for Solution A and C.R. 1 follows:

The cell performance rating is +2, 60/100 respondents chose M, and 40/100 respondents chose O, the redefined performance rating is (60/100) (0) + (40/100)(+2) = +0.8. This is then multiplied by the Self-Stated Importance Rating.

An example of a complete solution scoring using this method follows:

	Kano Dimension	Self-Stated Importance Ratings	A	B	C	D
C.R. 1	M :60 O:40	1	+2	+1	0	+1
C.R. 2	O:100	2	0	+1	-2	+2
C.R. 3	A:50 O:50	4	+1	0	+2	+1
C.R. 4	M:60 I:40	3	-1	+1	+2	0
Solution Scores			3.0	2.4	4.0	8.4

(Columns A–D: - - - - - Solutions - - - - -)

Solution A Score = [(60/100)(0) + (40/100)(+2)] x 1

+ [(100/100)(0)] x 2

+ [(50/100)(+1) + (50/100)(+1)] x4

+ [(60/100)(-1) + (40/100)(0)] x3 = 3.0

Metric-Based Scoring

This scoring method numerically assesses solution concepts but excludes Kano results. Fill out the metric-based Screening Matrix (cell-scores are -2,-1,0,1,and 2 as in the previous step), leaving an extra column for Metric Importance weights.

		- - - - - Solutions - - - - -			
	Metric Importance Weight	A	B	C	D
Metric 1		+2	+1	0	+1
Metric 2		0	+1	-2	+2
Metric 3		+1	0	+2	+1
Metric 4		-1	+1	+2	0
Solution Scores					

Determine Metric Importance Weight

The questionnaires in Step 7 allow you to determine an importance rating for each requirement. In this step, you convert that information into Metric importance weights by combining the correlation assessment from the Quality Chart (Step 9) with the Self-Stated Importance results (Step 7). This is a proxy measure of how strongly each metric relates to the performance of the entire product from the point of view of the customer. As an example, suppose we had the following Correlation Matrix:

		- - - - - - Metrics - - - - - -			
	Self-Stated Importance Ratings	1	2	3	4
C.R. 1	1	○			○
C.R. 2	2			○	
C.R. 3	4	⊙			○
C.R. 4	3	△	○		
Metric Weighting		17	6	4	10

Correlation Weights: ⊙ = High (3)
○ = Medium (2)
△ = Low (1)

For each metric, multiply each correlation by the Importance Rating of the corresponding requirement. (The Self-Stated Importance Rating is the average from all returned surveys for each customer requirement.) The sum of these products is the Metric importance weighting.

For Metric 1, there is a medium correlation with C.R. 1 (correlation factor = 2), and the Self-Stated Importance Rating = 5, a high correlation with C.R. 3 (correlation factor = 3) and Self-Stated Importance Rating = 4, and a low correlation with C.R. 4 (correlation factor =1), and Self-Stated Importance Rating = 1.

Weighting for Metric 1 = (2)(1) + (3)(4) + (1)(3) = **17**

Repeat the calculation for each metric and record the Metric Importance on the screening matrix.

		- - - - - Solutions - - - - -			
	Metric Importance Weight	A	B	C	D
Metric 1	17	+2	+1	0	+1
Metric 2	6	0	+1	-2	+2
Metric 3	4	+1	0	+2	+1
Metric 4	10	-1	+1	+2	0
Solution Scores					

Calculate Solution Scores

We now have all the information we need to score each solution. A solution's score will be the sum of its cell-performance ratings multiplied by the appropriate Metric Importance Weights.

In our example above, the score for Solution A is

(+2)(17) + (0)(6) + (+1)(4) + (-1)(10) = **28.**

Here is the screening matrix complete with scores ...

	Metric Importance Weight	Solutions A	B	C	D
Metric 1	17	+2	+1	0	+1
Metric 2	6	0	+1	-2	+2
Metric 3	4	+1	0	+2	+1
Metric 4	10	-1	+1	+2	0
Solution Scores		28	33	16	33

Solutions B and D are tied with the highest scores. Their strengths lie in different areas, but their total effectiveness is rated the same by this scoring algorithm. This represents an opportunity to create improved solution concepts through combination.

Tips

- It is not necessary to do both types of screening outlined in this step.
- The creation of additional solution concepts in this stage should be encouraged.
- Don't blindly follow the scoring steps; think about what makes sense based on your team's assessment. .You may find -, 0, + is satisfactory

Completion Checklist

At the completion of this step, a Solution Selection Matrix should be completed for every solution concept which received serious consideration.

Step 15: Reflect on the Process

Your team is at the final step of Concept Engineering, where you will make a decision on a product concept that you will present and defend when asking for resources to support development. At this step you should also reflect on the entire Concept Engineering process.

Decision Factors

There are many factors to consider in choosing the product concept:

Solution Scores

The team has collectively constructed solutions on paper, evaluated their performance vs. customer requirements, and scored them with appropriate weighting for Kano and Self-stated Importance Rating Data. These scores, developed by one or both scoring methods, should indicate the dominant concepts.

Intuitive Convergence

After the entire team has heard the same "voices of the customer," mapped out the requirement space, explored the solution space, and studied the Kano and Importance data, it is inevitable and beneficial that the development team form an opinion about which solution is the best concept. This is another basis for making the decision.

Company Capabilities

Manufacturing capabilities, distribution channels, resource constraints, and product family considerations are all factors which should be considered in the selection decision.

Company Philosophy

For a product to be approved for development, it must also be consistent with company philosophy. It is possible for solutions which meet market needs not to be consistent with company philosophy. Thus, company philosophy is an important factor to consider in making a final decision.

Final Concept Decision

Do not blindly select the concept with the highest score. Reflect on what you've learned. Consider factors which will ensure acceptance and support within the company and the distribution channel. The goal is to get your product into the market. The best product concept, if implemented poorly or not at all, will not make money.

Concept Presentation

You are ready to get commitment to the development of your product concept. Your team should have all the documentation needed to persuade senior management to support development of the product concept.

Concept Engineering Process Reflection

As in other TQM methods, Concept Engineering is not finished until the team reflects on its work and thinks about improvements to the process.

Reflect on how far the team has come, how much has been learned about the customers and their requirements. Think about the process, what worked well, what was difficult, what could be improved the next time. Document these thoughts and pass them along to others in the organization and to the CQM so that other companies can benefit through mutual learning.

Tips

- If your intuition and scores don't match, follow the data trail backwards from solution scoring. Pay close attention to the points where your intuition disagrees with the highest scoring solutions. This may be a clue to an error or omission along the way. When these final differences, if any, are ironed out, the team must commit to a single concept that they will support and defend.
- If there are challenges and objections to your concept, you have a complete self-documented audit trail showing how you arrived at your final solution, along with a very large and defensible list of things not to do.
- Comments on Concept Engineering can be sent to the CQM or to Gary Burchill at (617) 258-5586 or Diane Shen at (617) 873-3730.

Completion Checklist

At the completion of this step you should have commitment from your Development and Management team to proceed to detailed specification of the selected concept and notes from the team's reflection on the process.

Appendix A: Glossary

Concept Engineering: a process for determining customers' key requirements, creating a measurement plan for assessing compliance with the requirements, and developing a strong product or service concept which satisfies the requirements. Concept Engineering has 5 stages: Understanding the Customer's Environment, Converting Understanding into Customer Requirements, Operationally Defining Customer Requirements, Generating Solutions, and Selecting a Solution.

Concept Description Sheets: a one-page or less description of a combination of ideas which make up a solution concept; developed at the end of Stage 4, and used in Stage 5, Selecting the Concept.

Correlation Matrix: one of the Seven Management and Planning Tools used to look at the relationship between two sets of items; the Quality Chart in Stage 3 of Concept Engineering is a correlation matrix which examines the relationship between Customer Requirements and metrics in order to choose the smallest set of metrics which covers the set of Customer Requirements.

Customer Requirements Statements: the outcome of translating the voice of the customer into requirements; a descriptive sentence stating a customer need, not a solution.

Customer Requirements Worksheet: a four-column sheet for use in translating the Voice of the Customer into Customer Requirement Statements in Step 4 of Concept Engineering.

Customer Voices: the first column on the Customer Requirement Worksheet; the actual words of the customer; each customer voice is a complete thought.

Decomposition: the first step in Stage 4, Concept Generation, in which the team breaks the problem or objective into components by using the Requirements KJ, Metrics Tree, process flow, or other methods; solutions will be generated for each segment and then combined to form whole product concepts.

Image: a mental picture of an aspect of the customer's environment collected from a customer visit, either from something a customer said or from an observation of their environment; the second column in the Customer Requirements Worksheet, used to link a customer voice to an

aspect of the customer's context to help in the interpretation of the voice.

Image KJ: a KJ of a collection of images, or scenes, about the customer's environment; a common mental model of the customer's context in which the team's product or service will be used.

Kano Survey: a customer research tool used to learn more about a set of Customer Requirements; developed by Noriaki Kano this questionnaire is used to determine requirement dimensions, one-dimensional (more functionality leads to more customer satisfaction, less functionality leads to less satisfaction), Attractive (if present, leads to satisfaction, if not present customer is neutral), and Must-Be (if functional, customer is neutral, if not functional customer is greatly dissatisfied).

Key Items: the third column on the Customer Requirements Worksheet; the main thoughts or key ideas from the combination of the Customer Voice and the image; a bridge from the fuzzy voice of the customer to the clear, concise Customer Requirement.

Ladder of Abstraction: a semantics concept described by S.I. Hayakawa; levels at which we select characteristics to describe an object of our experience; lower levels on the ladder contain more characteristics of one object, terms on higher levels contain fewer characteristics of one object to describe what is common among many objects; items lower on the ladder are more factual, items higher on the ladder are more conceptual.

Lead Users: a term used by Eric von Hippel to describe users of a product or service who have certain characteristics which set them apart and make them good targets for product development teams to work with in developing product concepts; among these characteristics are prototype experience, a strong need for a solution to the problems they are experiencing, and an ability to articulate the problem and possible solutions.

Market-In: a concept introduced by Professor Shiba; work is a means not an end, the end is customer satisfaction and everyone has a customer.

Mental Excursions: a technique for generating solution ideas in which you concentrate on the area of focus while reflecting on the Image KJ of the customer's environment

Metric Scoring : a scoring method of numerically assessing solution concepts in Stage 5 which combines the correlation assessment from the Quality Chart with the Self-Stated Importance ratings.

MPM (Multi-stage Picking-out Method): one of the methods associated with KJ developed by Jiro Kawakita; a tool by which a team can systematically reduce a large amount of data to the vital few items.

Net-Touching: one of the methods developed by Jiro Kawakita, a tool for sorting and classifying language data; organization is done logically as compared to intuitively in the KJ method; Unlike KJ, Net-touching does not lead to new insight but instead helps to quickly give some order to a set of language data.

Operational Definition of a Customer Requirement: a description of a metric including how the data will be collected and displayed.

Plus - Minus - Interesting: an approach for systematically exploring the strengths and weaknesses of a solution idea.

Quality Chart: a correlation matrix used in stage 3 to assess the metrics against the customer requirements in order to choose the smallest set of metrics which will cover the set of requirements; also called the "first house of quality."

Reference Concept: used in Stage 5, Step 13, Screen Solutions. In order to score each potential solution a reference solution is chosen for comparison; the reference solution concept can be the "best in class," the current product, or a competitor's product.

Requirement Importance rating : a way of incorporating the Self-Stated ratings into Step 14, Select the Solution; an average of all returned Self-Stated surveys.

Screening matrix: a correlation matrix used in Stage 5, Selecting the Concept; it compares solutions against either requirements or metrics and by using a reference concept, scores each of the solutions.

Self-Stated Importance Questionnaire: a customer survey tool; customers give a score ranking the importance of each requirement; can be used in conjunction with the Kano Survey.

Solution Concepts: ideas for product or service components are combined to form complete solution ideas, or solution concepts.

Swim in Shallow Water: developed from Shiba's swimming in the fishbowl concept; a term used to describe practice customer visits with internal or friendly customers before conducting external visits.

Voice of the Customer: a verbatim transcript of the actual words of the customer collected in a face-to face visit or telephone call.

WV Model: the systematic problem-solving model developed by Jiro Kawakita and Professor Shiba, which describes problem-solving as a series of steps alternating between the level of thought and the level of experience; contains the 7 step reactive problem solving method.

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Appendix C: Additional Hints on Administering Surveys

Response Rate

Survey response rates can vary all over the board. For busy professionals such as doctors, response rates to mass mailings can be as low as one percent. Take heart, though. Generally, response rates are much higher among customers (and particularly those you have visited).

You will probably see lower response rates among former customers and prospects. Market research firms often maintain statistics on response rates sorted by profession. Such information may be useful in planning the size of the mailing you need to meet your target response.

Experience suggests that 95% of those who will respond at all will do so in three to four weeks. If you don't have your target response by then, you should either follow up or do a supplementary mailing.

Tips to improve response rate

- First Class postage
- Personalized letter
- Incentives
- Post card warning prior to sending questionnaire
- Post card follow-ups

- Professional appearance to survey. This could include any or all of the following:

  20 lb. stock, smooth, non-slick paper, matching envelopes, colors (white, off-white, very light gray, beige, olive green ,or cream), black ink, same font throughout, boxes to highlight sections, hand signature in blue ink, standard size 8 1/2" x 11", flat 8 1/2" x 11" envelope to deliver questionnaire (more professional, attracts attention), clean and simple layout, full use of white space, use of graphics if warranted, booklet form, shading, page numbers in upper right corner, "Please continue on page x" at bottom of page if warranted, note at end thanking respondent, title printed at top of each page, color code by target group if necessary.

Suggestions for the Cover Letter

The cover letter should address the following questions:

- What this is about?
- Who wants to know?
- Why do they want to know?
- Why was I picked?
- How important is this?
- Will this be difficult?
- How long will this take?
- Will it cost me anything?
- How will this be used?
- Will I be identified?
- What's in it for me (benefits, incentive, token of appreciation)?
- When should I do it (deadline)?

Example Letter of Introduction

Dear {company} customer,

At {company} we recognize that your input must play a vital role if we are to develop products that meet your needs. We are writing, therefore, to solicit your views regarding {product} features and capabilities with the intention of using your input to enhance {product} or to develop new products to better meet your needs.

The enclosed questionnaire is the result of an effort by the {product} development team to apply Total Quality Management methodologies to investigate user requirements in the area of {product category}. As part of the method for determining user requirements, we visited a representative sample of {product} customers and non-customers, and we recorded their comments regarding the types of tasks they are faced with, the problems they encounter and so on. We have analyzed these data and developed some conclusions about {product category} features and capabilities that users like yourself require, and we would like to check the validity of our conclusions by having you answer some questions for us.

Although some of the questions we ask may appear redundant, they were all carefully chosen to gather the information we feel we need to guide us in designing and developing quality {product category} that meets your needs. The survey should take about thirty minutes to fill out. Please return the completed questionnaire in the enclosed, self-addressed envelope by xxx.

Sincerely,

XXXXX
{Product} Development Manager

P.S.: To thank you for your time, a {product} T-shirt will be sent to each respondent who completes and returns the enclosed questionnaire. The questionnaire includes a space for you to indicate your preferred size.

Appendix D: Kano

Understanding Kano Theory

Kano analysis helps us understand the relationship between the fulfillment (or non-fulfillment) of a requirement and the satisfaction or dissatisfaction experienced by the customer. Working with social science theories on satisfaction developed by Frederick Herzberg, Kano discovered that the relationship between fulfillment of a need and the satisfaction or dissatisfaction experienced is not necessarily linear (although this was the prevailing assumption at the time). He found that he could sort requirements into distinct classes, and that each class would exhibit a different relationship with respect to satisfaction.

Kano's theory sorts customer requirements into five categories (described below). A sixth category, "Questionable Result," indicates a potential problem with the questionnaire. A brief definition for each of Kano's dimensions is listed below:

A Attractive Quality Elements: Customer Requirements which create satisfaction when fulfilled, but are accepted as is even when not fulfilled. In other words, the customer is greatly satisfied when this element is present but experiences no dissatisfaction when it is not present. In the stripping basket case, the ability to wear the basket in different positions was rated Attractive.

O One-Dimensional Quality Elements: Requirements which result in rising satisfaction the more they are fulfilled, but lead to increasing dissatisfaction when less fulfilled. There is a proportional relationship between functionality and satisfaction. The water drainage rate is an example of a One dimensional element for the stripping basket.

M Must-Be Quality Elements: Requirements which do not lead to satisfaction when fulfilled but cause dissatisfaction when not fulfilled. Tangle-free casting was a Must-be element for the stripping basket.

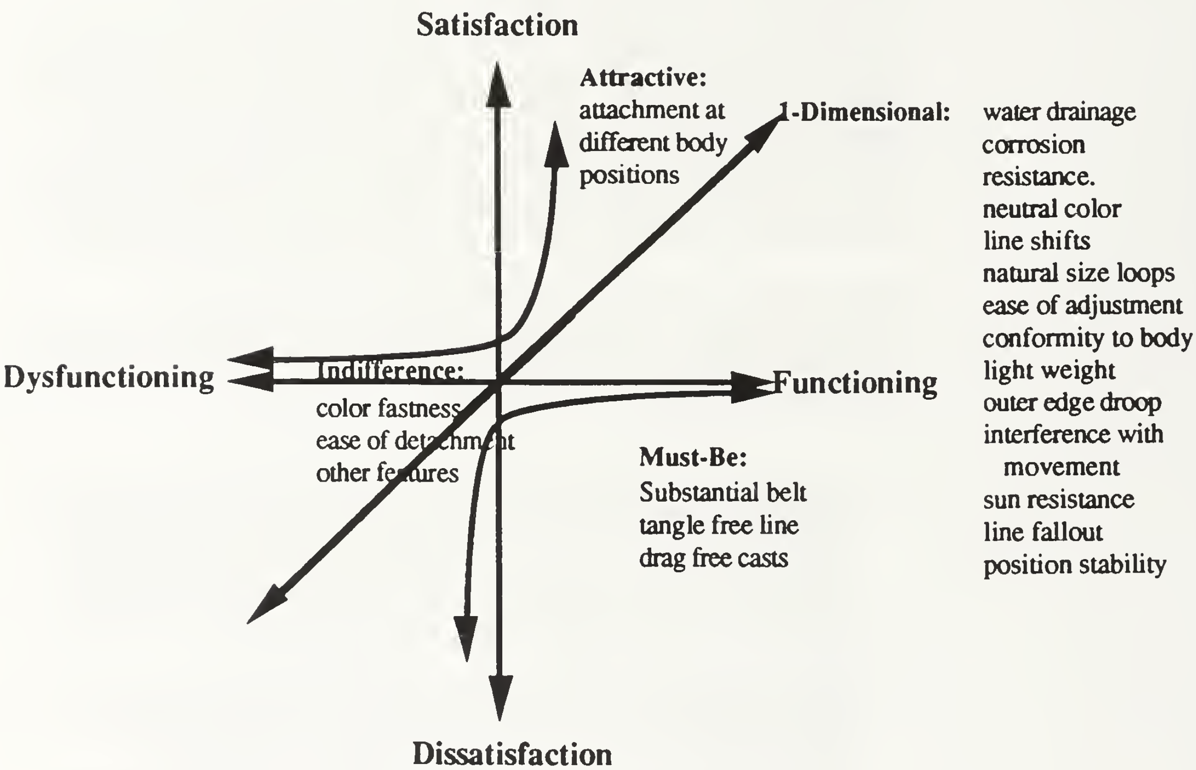
I Indifferent Quality Elements: Requirements which result in neither satisfaction nor dissatisfaction regardless of whether they

have been fulfilled. Color-fastness was rated as an Indifferent requirement for the stripping basket.

R Reverse Quality Elements: Requirements which result in dissatisfaction even when fulfilled or in satisfaction even when not fulfilled. (This usually indicates a problem in the question.)

Q Questionable Result: May result from an error in the data-gathering process, or from an erroneous assumption about what is a functioning (or dysfunctioning) question.

The relationship between the above three critical categories and the satisfaction or dissatisfaction experienced by the customer is expressed graphically below. Indifferent elements are represented by the x-axis.



It is important to note that the axes in the above diagram are asymmetrical, that dissatisfaction is not the opposite of satisfaction. When an Attractive requirement goes unfulfilled, the result is not dissatisfaction, but simply a lack of satisfaction. In contrast, fulfilling a Must-be requirement does not produce satisfaction. It only avoids

dissatisfaction. Only one class of requirements behaves as if the positive and negative axes were continuous: One-dimensional factors. These requirements can induce reactions ranging from dissatisfaction, through indifference, to satisfaction, depending on how well they are fulfilled.

The Kano question pairs will help us to locate each requirement on the above graph. When pieced together, the answers to a functioning/dysfunctioning question pair identify which of the five categories a given customer need fits into. The process of merging the information contained in these response pairs is the purpose of the Kano evaluation table described in the section, "Processing Results." As an example, though, a response to the functioning question of "I like it that way" generally indicates that the requirement fits somewhere in the right side of the above diagram, along the satisfaction axis. The response to the dysfunctioning question would pin down the requirement as either Attractive or One-dimensional.

The quality element curves are not necessarily stable over time. The curves can shift down and to the right over time as the market becomes conditioned to expect certain features. Thus, a feature once considered Attractive, such as the remote control for a television set, could move over time into the One-dimensional category, and ultimately become a Must-be requirement. This phenomenon is termed "quality satisfaction decay" by Professor Shoji Shiba.

In developing and testing the questionnaire, you became familiar with the five standard responses to each of the question pairs (ranging from "I like it that way" to "I dislike it that way"), and may be curious about the order in which they appear. The logic behind the arrangement of the responses is the level of pleasure experienced by the customer. A scale of pleasure is known as a hedonic scale.

The question is frequently posed: why is "I like it that way" a stronger statement of pleasure than "It must be that way?" Consider these responses in the context of Kano's functioning question. The thought behind this ordering is that the first response signifies a type of positive satisfaction, while the latter relates to avoidance of displeasure. Additional investigation of the hedonic scales is currently in progress.

Continuous/Graphical Analysis

There are two powerful advantages to using continuous variables:

- A continuous approach can summarize the data without losing resolution. For example, in the Kano evaluation table there are nine response pairs which equate to the "Indifferent" dimension,and each may have a somewhat different emphasis.
- A continuous representation deals more comfortably with situations where there is no dominant response to a question (e.g., 37% Must-Be, 33% Attractive, 30% One-Dimensional) by allowing for intermediate points, or hybrids. See the caveat below, however.

Caveat: The continuous analytical approach described here is best applied after inspecting responses for evidence of discrete market segments. Lumping together distinctly different perspectives to form an average may produce confusing results. Take, for example, a case where votes are evenly split between "Attractive," "Must-Be," and "One-Dimensional." One way to check for the existence of distinct segments is to run a test of correlation between this response variable and some of the demographic data collected with the questionnaire. When different segments are identified, we suggest handling the data separately.

To solve the problem of data loss, we can assign each response a numerical value, establishing a scale. We propose the following levels for the functioning and dysfunctioning responses:

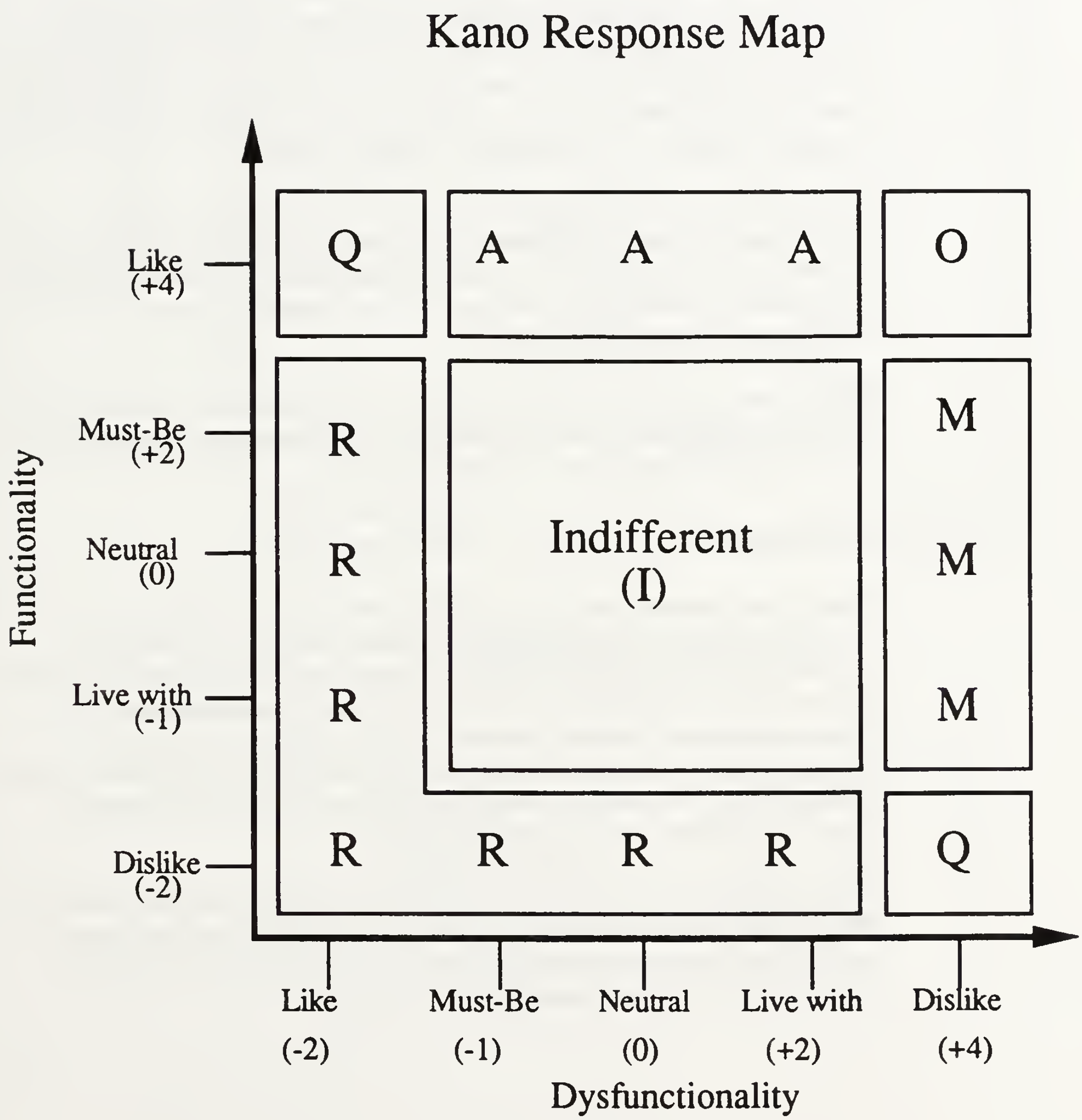
Functioning	Dysfunctioning
Like=4	Dislike=4
Must be=2	Live with=2
Neutral=0	Neutral=0
Live with=-1	Must be=-1
Dislike=-2	Like=-2

Each of the Kano dimensions may now be represented as a coordinate pair:

	X	Y
Reverse	-2	-2
Indifferent	0	0
One-dim.	4	4
Must-Be	4	0
Attractive	0	4

These coordinates will serve as reference points for the other data (when averages are taken across large data sets, rarely will there be "pure" Must-be or Attractive requirements). Answers generally lie somewhere in between. With this continuous representation, we can retain that information.

The logic for the asymmetrical scale (beginning from -2, rather than -4) is that Must-be and One-dimensional dimensions are stronger responses than Reverse, or Questionable. Therefore, our scaling should give less weight to such responses to diminish their influence on the average. The following map should help to clarify the positioning of the various dimensions. You may want to compare it to the Kano evaluation table presented earlier.



For each Kano question, compute the average of the functional responses (these will be mapped on the y-axis) and the average of the dysfunctional responses (to be mapped on the x-axis). With a properly designed survey, the averages should fall in a range of 0-4, since negative values (which indicate questionable or reverse dimensions) should be in the minority.

We can now form a grid (shown opposite), with Xave and *Yave* ranging from 0 to 4 on each axis. Note that each corner of the grid represents a prototype, a pure result. For instance, if all respondents to a given survey question answered "like" to the functional portion and "dislike" to the dysfunctional piece, the coordinates of the average response would be (X=+4, Y=+4), indicating a pure One-dimensional requirement.

Notice that the square is divided into quadrants. When the pairs of coordinates representing the average responses to each of the Kano questions have been plotted on the grid, the nature of each requirement is clearly delineated by the quadrant into which that point falls. For instance, a requirement such as number 5, which falls into the upper left quadrant, should be viewed as an Attractive element.

The closer a point falls to one of the four labeled corners (the prototypes), the more unanimous the survey respondents must have been in their views. Conversely, a point such as number 9, which falls near the center of the diagram, is a fuzzier result which indicates disagreement among respondents.

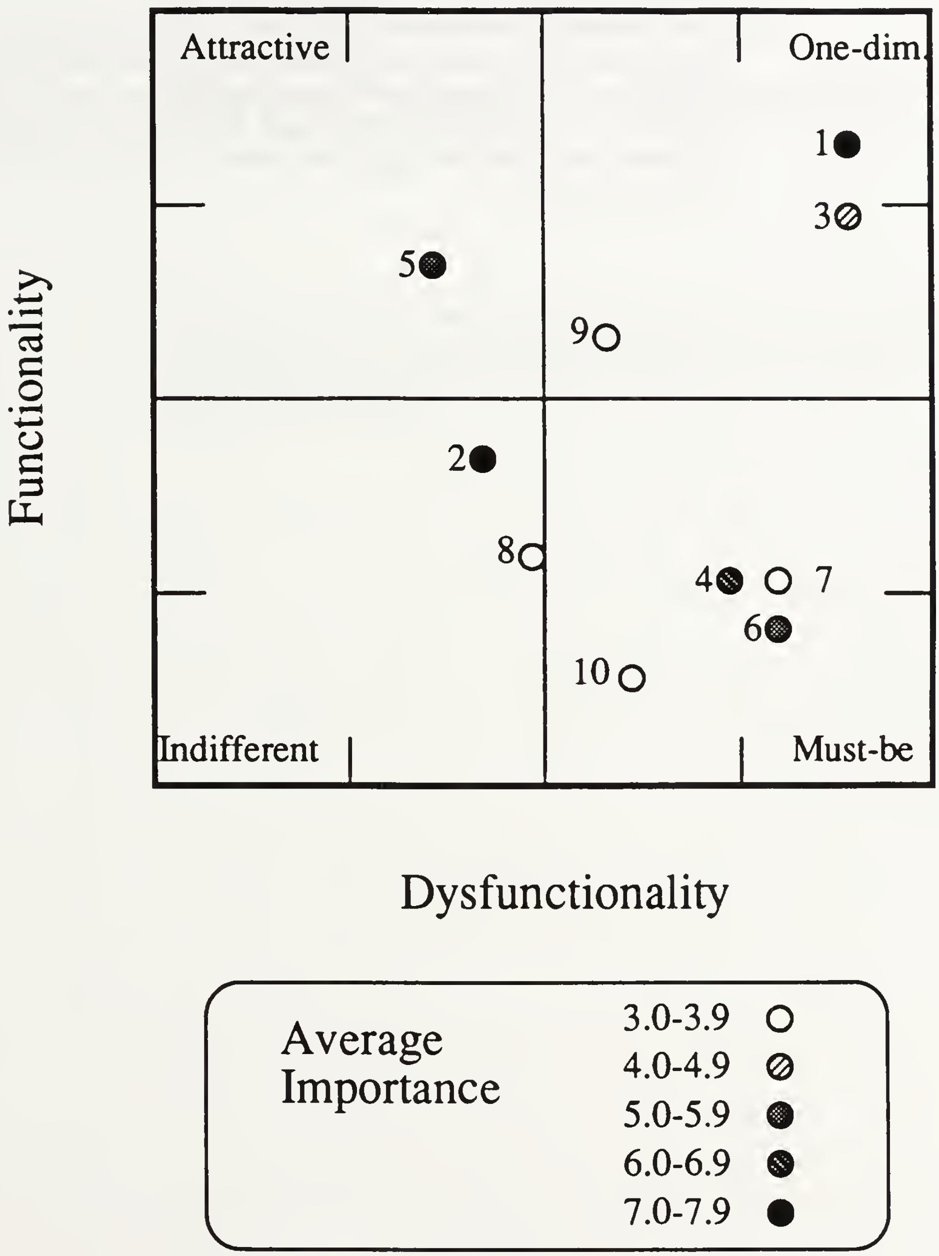
Shading each point according to the average importance vote for that requirement is an easy way to integrate the information obtained from the Self Stated Importance questionnaire.

Interpretation

There is no hard-and-fast way to interpret the diagram for development priorities. The best approach might vary with the number of points falling into each quadrant, with the clustering of the points within a quadrant, or with the degree of differentiation of importance levels within a quadrant. For instance, in the above diagram, there is only one Attractive element. Although it ranks only as medium in importance, the team might believe that the product needs a differentiating characteristic.

What makes the most sense is for your group to view the grid (perhaps without the points numbered, in order to maintain objectivity about which requirements should be pursued), and then agree on a decision rule that will work for your data.

Average Functionality vs. Average Dysfunctionality
(Coded by Average Importance, and with Questions Numbered)



Possible enhancements

- Use the importance votes to weight the Kano responses. Using this method means that the more importance a respondent ascribes to a given requirement, the greater his or her influence will be in classifying the requirement as One-dimensional, Must-Be, etc.. Remember to use the weighted version of standard deviation if you want to include error bars on this graph.
- Where responses to a particular question have been grouped into distinct market segments, plot all the points on one graph, but in different colors. If the graph becomes too cluttered, you may have to omit the information on variation or importance. To avoid losing the importance data, you might vary the color only on the number next to each point.

Appendix E: Concept Engineering Process Metrics

The metrics subcommittee of the CQM Research Committee has been investigating product development process metrics. This appendix is contained in the Autumn '92 issue of the Center for Quality Management Journal.

Appendix F: Concept Engineering Worksheets

Customer Voice	Image	Key Item	Requirement Statement

Metric Development Worksheet

Customer Requirement:______________________________

Ambiguity:

Everyone interprets differently		A difference in interpretation exists		Possibilities for multiple interpretations exist		Everyone agrees on meaning
1	2	3	4	5	6	7

Metrics	Validity	Feasibility	Rank

Kano Questionnaire Worksheet

1a.	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it.
1b.	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it.

2a.	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it.
2b.	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it.

3a.	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it.
3b.	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it.

4a.	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it.
4b.	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it.

5a.	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it.
5b.	1. I like it that way. 2. It must be that way. 3. I am neutral. 4. I can live with it that way. 5. I dislike it.

Self-Stated Importance Rating Worksheet:

	Not at All Important		Somewhat Important		Important	Very Important		Extremely Important	
1. *How important is it or would it be if:*	1	2	3	4	5	6	7	8	9
2. *How important is it or would it be if:*	1	2	3	4	5	6	7	8	9
3. *How important is it or would it be if:*	1	2	3	4	5	6	7	8	9
4. *How important is it or would it be if:*	1	2	3	4	5	6	7	8	9
5. *How important is it or would it be if:*	1	2	3	4	5	6	7	8	9
6. *How important is it or would it be if:*	1	2	3	4	5	6	7	8	9
7. *How important is it or would it be if:*	1	2	3	4	5	6	7	8	9
8. *How important is it or would it be if:*	1	2	3	4	5	6	7	8	9
9. *How important is it or would it be if:*	1	2	3	4	5	6	7	8	9
10. *How important is it or would it be if:*	1	2	3	4	5	6	7	8	9

Plus - Minus - Interesting Worksheet

Concept Description:	
P	
M	
I	

CQM

MEETING ANNOUNCEMENT

The Center for Quality Management
150 CambridgePark Drive, Cambridge, MA 02140
Tel#: (617) 873-2152 Fax#: (617) 873-2155

Please deliver a copy of this fax to each person in your company at the receiving fax number listed below.

TO: CE User's Group

NAME:	COMPANY:	PHONE#:	FAX #:
Alan K. Graham	Center for Quality Management	Hm (508) 369-8714	CQM (617) 873-2155
John H. Petrolini	Teradyne, Inc.	(617) 422-2216	(617) 422-2910
Diane Shen	Bolt Beranek and Newman Inc.	(617) 873-3730	(617) 873-5011
Gary Burchill	MIT	(617) 258-5586	(617) 258-7579
Yogesh Parikh	Digital Equipment Corporation	(508) 493-1551	(508) 493-6094
Ralph P. Anderson	BTU International	(508) 667-4111	(508) 667-9068
Peg Doyle	Praxis International Inc.	(617) 661-9790	(617) 497-1072
Joe Kasabula	Polaroid Corporation	(617) 577-5056	(617) 577-4022
David Boger	Bose Corporation	(508) 879-7330	(508) 820-4865
Hugh Loveday	Ford Motor Company	(313) 322-0886	(313) 322-4033
Christina Brodie	Polaroid Corporation		(617) 577-2882
Bill Fetterman	Analog Devices, Inc.		(617) 937-2000
Dawn Dougherty-Fitzgerald	MIT		(617) 253-5771
Pam Chan	EPA		
Mark Martin	MIT	(617) 253-2229	(617) 253-5771
Mike Timko	Analog Devices, Inc.	(617) 937-1257	(617) 461-4496
Elise Locker	Bolt Beranek and Newman Inc.	(617) 873-6327	
Christopher Moore	Bose Corporation	(508) 879-7330	(508) 872-6541

FROM: Ted Walls **PAGE #:** 1 **DATE:** 3/5/93

RE: Monthly Meeting

The CE User's Group minutes and Meeting Announcement are attached, with addenda from the meeting.

CQM

150 CambridgePark Drive,
Cambridge, MA 02140
Tel #: (617) 873-2152 Fax #: (617) 873-2155

MINUTES

CE User's Group

Feb 19, 1993 at Bose Corp, Framingham

In attendance: Ralph Anderson, BTU; Mike Timko, Analog Devices; Elise Locker, BBN; Christopher Moon, Bose; Yogesh Parikh, DEC; Jay Thomas, Sippican; Joe Kasabula, Polaroid; Gerry Waldron, BTU; Marty Soderlund, BTU; Diane Shen, BBN; Gary Burchill, MIT, Mark V. Martin, MIT; Hugh Loveday, Ford; Dawn Doherty Fitzgerald, MIT; David Boger, Bose.

Next Meeting

Friday, March 19, 1993, from 3 to 6 PM, at Polaroid. The CE User's Group meets the third Friday of every month.

Highlights

1. Mike Timko, (Analog Devices) presented a method for using results of the Kano and Self stated Importance Questionaires in Concept Selection. Mike has developed an Excel Spreadsheet which uses the "Attractive", "Must Have", One Dimensional", and "Indifferent" scores directly with the SSI values to generate the "better than", and "worse than" factors. (Eliminates the need to decide the Kano category.)

2. David Boger (Bose) (discussed the use of Concept Engineering Techniques to establish "Fitness for Use" during Alpha-Testing of a product. This structured method used voice of the customer interviewing of a number of people (12-20) who used an engineering sample of a product for a short period. (2 weeks?)

CE methods were used to "explore" the responses, develop requirements, weight and prioritize the opportunities for improvement.

This Alpha testingwould have been easier if the project had been started using CE techniques (SSI and Kano factors available).

The reaction by the development team to the results was very favorable, with appreciation for the clarity of the list.

3. The announcement for upcoming CE course was reviewed, with minor changes suggested.

The leaders of the day were were agreed upon as follows:

		Leaders	Assistants
Day 1 Steps 1,2	May 3	John Petrolini (Teradyne) Diane Shen (BBN)	State Siting Board
Day 2 Steps 3,4	May 5	Christina Brodie (Polaroid) Ralph Anderson (BTU/CQM)	State Siting Board
Day 3 Steps 5,6,7	May 7	David Boger (Bose)	Diane Shen (BBN) State Siting Board Sippican (J. Thomas)
Day 4 Steps 7,8	May 11	Elise Locker (BBN) Kenny Likis (BBN)	Sippican (J. Thomas) ....Praxis (P.Doyle)
Day 5 Steps9, 10-15	May 13	Joe Kasabula (Polaroid) Mark Skilling or Bruce Amazeen (Analog)	.........Praxis (P.Doyle)

note: 1. Yogesh Parikh has offered to fill in where needed
2. Diane Shen may get substitute for 1 Day.

Leaders of the Day are requested to have copy ready masters of their material to CQM by April 14.

4. Dawn Dougherty Fitzgerald and Mark Martin (MIT Leaders of Manufacturing Program) reviewed the feedback from the LOM Concept Engineering Course in January. (5 each of 1/2 day session)

They abstracted the KJ results of the weaknesses--mainly insufficient time and inexperience of the instructor with teaching the material.

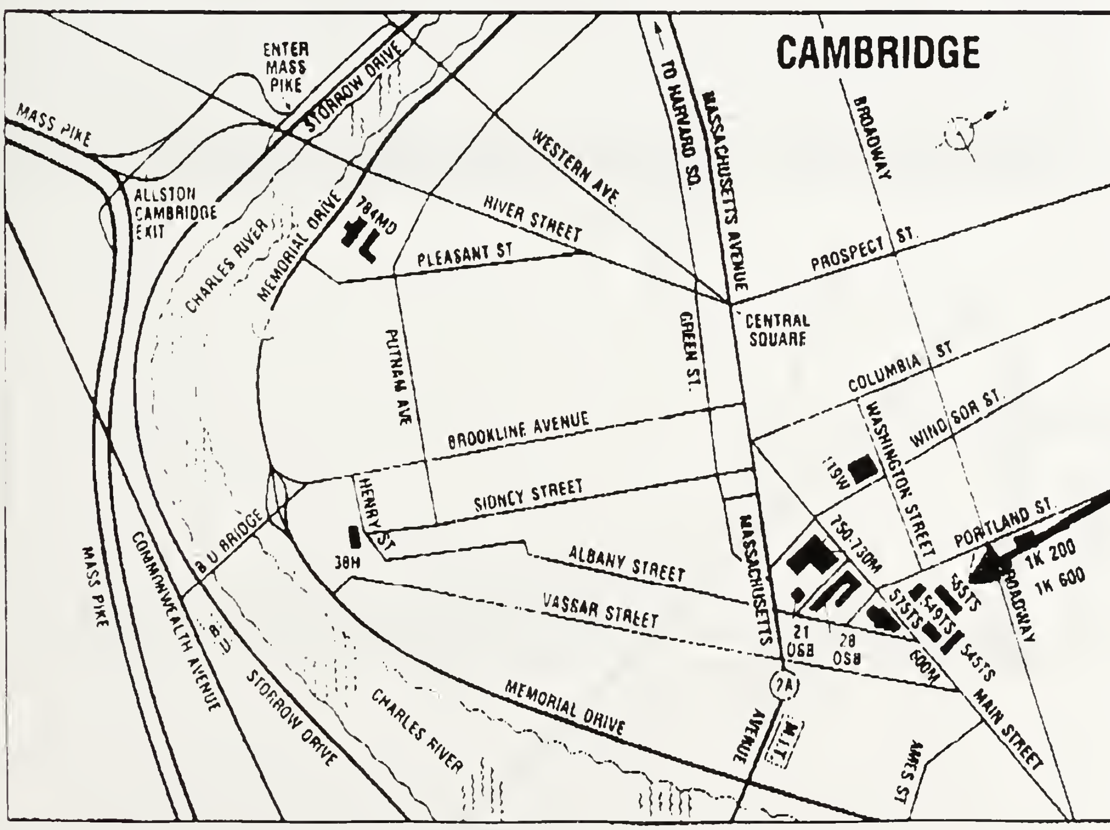
Gary Burchill led an effort to capture suggestions for improvement (Labels collected by stage of CE) the upcoming course.

Concept Engineering User's Group

Date:	Friday, March 19, 1993
Time:	2:00 to 5:00PM
Location:	Polaroid Corporation 565 Technology Square, 1st floor Cambridge, Ma 02139 Joshua Conference Room
Called By:	Joe Kasabula Phone 617-577-5056
Coordinator:	Ted Walls Center for Quality Management Please RSVP Phone 617-873-2152 Fax 617-873-2155

BUILDING CODES AND SITE MAPS IN MASSACHUSETTS

Boston:		
Inner City 716 Columbus Avenue (Zip Code 02120-2193)	COLUMB	PTN 8-221-XXXX
Cambridge:		
1 Kendall Square (Zip Code 02139-1563)	1KS600	PTN 8-221-XXXX
2 Osborn Street (Zip Code 02139-3591)	OSB2	PTN 8-221-XXXX
21 Osborn Street (Zip Code 02139-3500)	OSB21	PTN 8-221-XXXX
28 Osborn Street (Zip Code 02139-3590)	OSB28	PTN 8-221-XXXX
38 Henry Street (Zip Code 02139-4894)	38H	PTN 8-221-XXXX
119 Windsor Street (Zip Code 02139-3606)	WR	PTN 8-221-XXXX
545 Tech Square (Zip Code 02139-3561)	545TS	PTN 8-221-XXXX
549 Tech Square (Zip Code 02139-3589)	549TS	PTN 8-221-XXXX
565 Tech Square (Zip Code 02139-3586)	565TS	PTN 8-221-XXXX
575 Tech Square (Zip Code 02139-3587)	575TS	PTN 8-221-XXXX
600 Main Street (Zip Code 02139-3585)	600M	PTN 8-221-XXXX
730 Main Street (Zip Code 02139-3584)	730M	PTN 8-221-XXXX
750 Main Street (Zip Code 02139-3583)	750M	PTN 8-221-XXXX
784 Memorial Drive (Zip Code 02139-4687)	784MD	PTN 8-221-XXXX



To park, you must either get clearance from a guard, or leave license at desk in exchange for an access card to the garage.

Concept Selection Spreadsheet

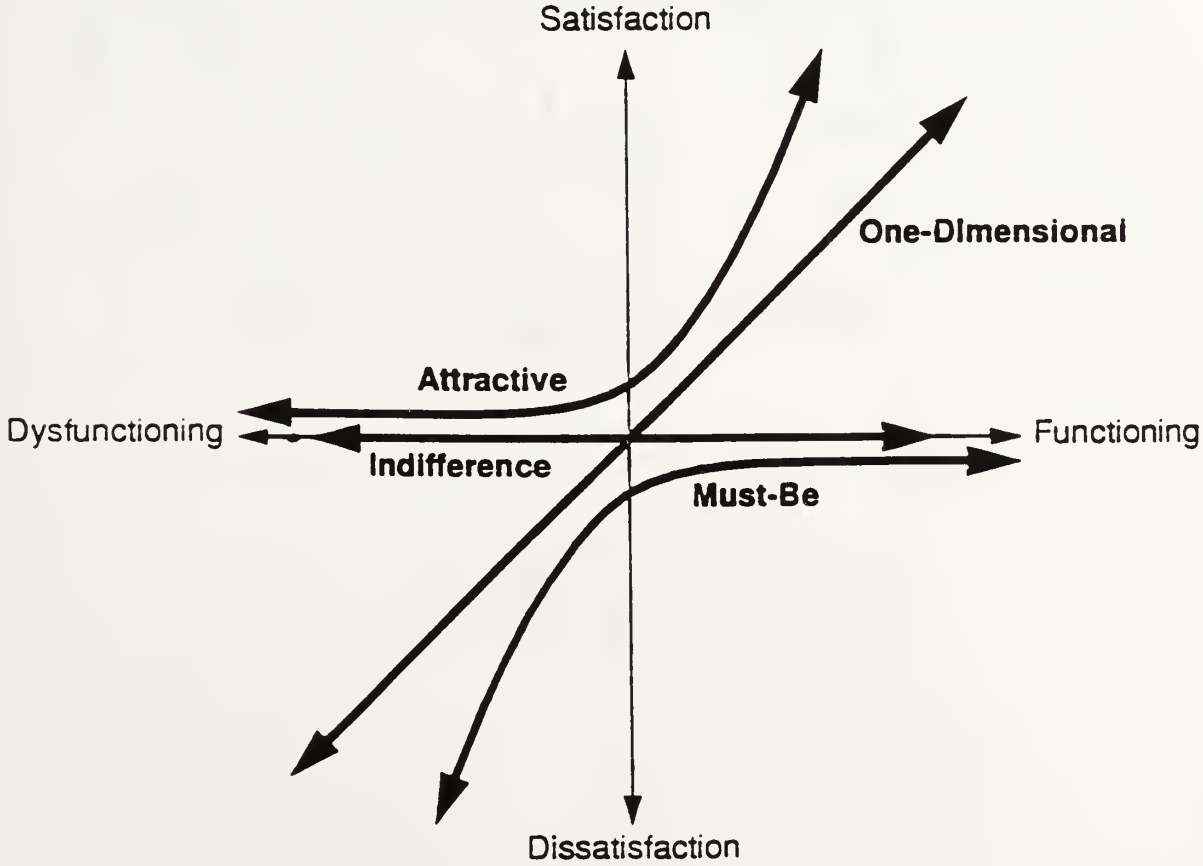
Title

Kano Questions		Questionnaire Data						Averaged scores	
Question number	CUSTOMER REQUIREMENT	Kano Dimension				SSI Rating	No. of Resp.	If we're better...	If we're worse...
		A	M	O	I				
9		17	43	43	10	6.6	113	+3.5	-5.0
13		28	25	53	10	6.8	116	+4.8	-4.6
23		12	63	19	19	6.0	113	+1.6	-4.3
14		45	21	41	8	6.5	115	+4.8	-3.5
12		35	23	32	18	6.5	108	+4.0	-3.3
6		53	20	35	6	6.8	114	+5.3	-3.3
5		40	17	33	24	6.6	114	+4.2	-2.9
10		62	13	25	10	6.5	110	+5.2	-2.3
19		43	14	21	27	5.7	105	+3.5	-1.9
17		72	10	22	11	6.0	115	+4.9	-1.7
4		59	8	26	18	4.9	111	+3.8	-1.5
15		74	5	20	16	6.0	115	+4.9	-1.3
18		65	11	14	21	5.7	111	+4.1	-1.3
26		64	5	17	29	5.7	115	+4.0	-1.1
3		55	3	20	30	5.1	108	+3.5	-1.1
20		68	4	16	22	5.7	110	+4.4	-1.0
2		69	4	16	27	5.2	116	+3.8	-0.9
25		44	8	14	50	4.7	116	+2.3	-0.9
21		54	4	9	45	4.8	112	+2.7	-0.6
16		64	3	10	38	4.8	115	+3.1	-0.5
24		32	7	6	56	4.1	101	+1.5	-0.5
11		56	3	10	47	4.6	116	+2.6	-0.5
8		76	2	7	26	5.0	111	+3.8	-0.4
22		66	1	8	40	4.1	115	+2.7	-0.3
1		40	2	2	60	4.2	104	+1.7	-0.2
7		63	1	1	20	4.5	85	+3.4	-0.1

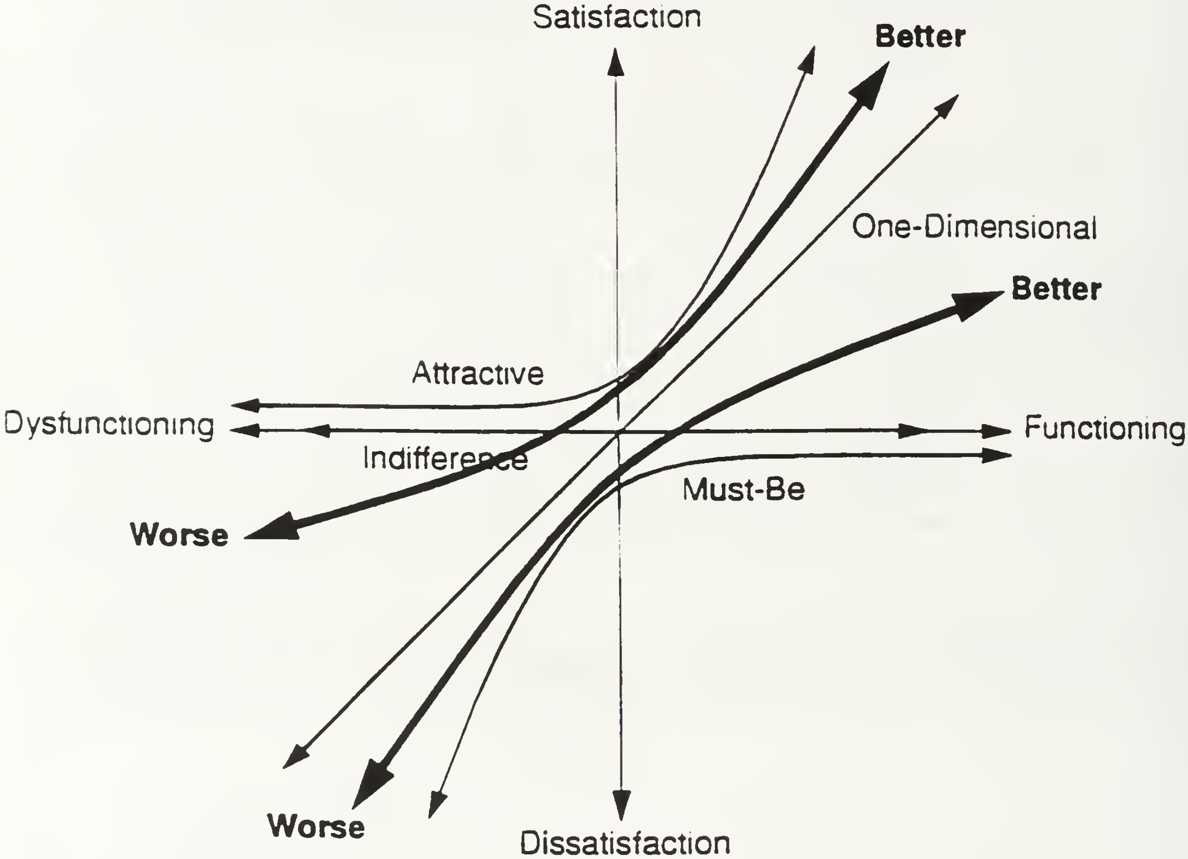
Table 1: Two Dimensional Table of Evaluation

		Dysfunctioning				
		1. like	2. must-be	3. neutral	4. live with	5. dislike
Functioning	1. like	Q	A	A	A	O
	2. must-be	R	I	I	I	M
	3. neutral	R	I	I	I	M
	4. live with	R	I	I	I	M
	5. dislike	R	R	R	R	Q

Kano Questionnaire Interpretation



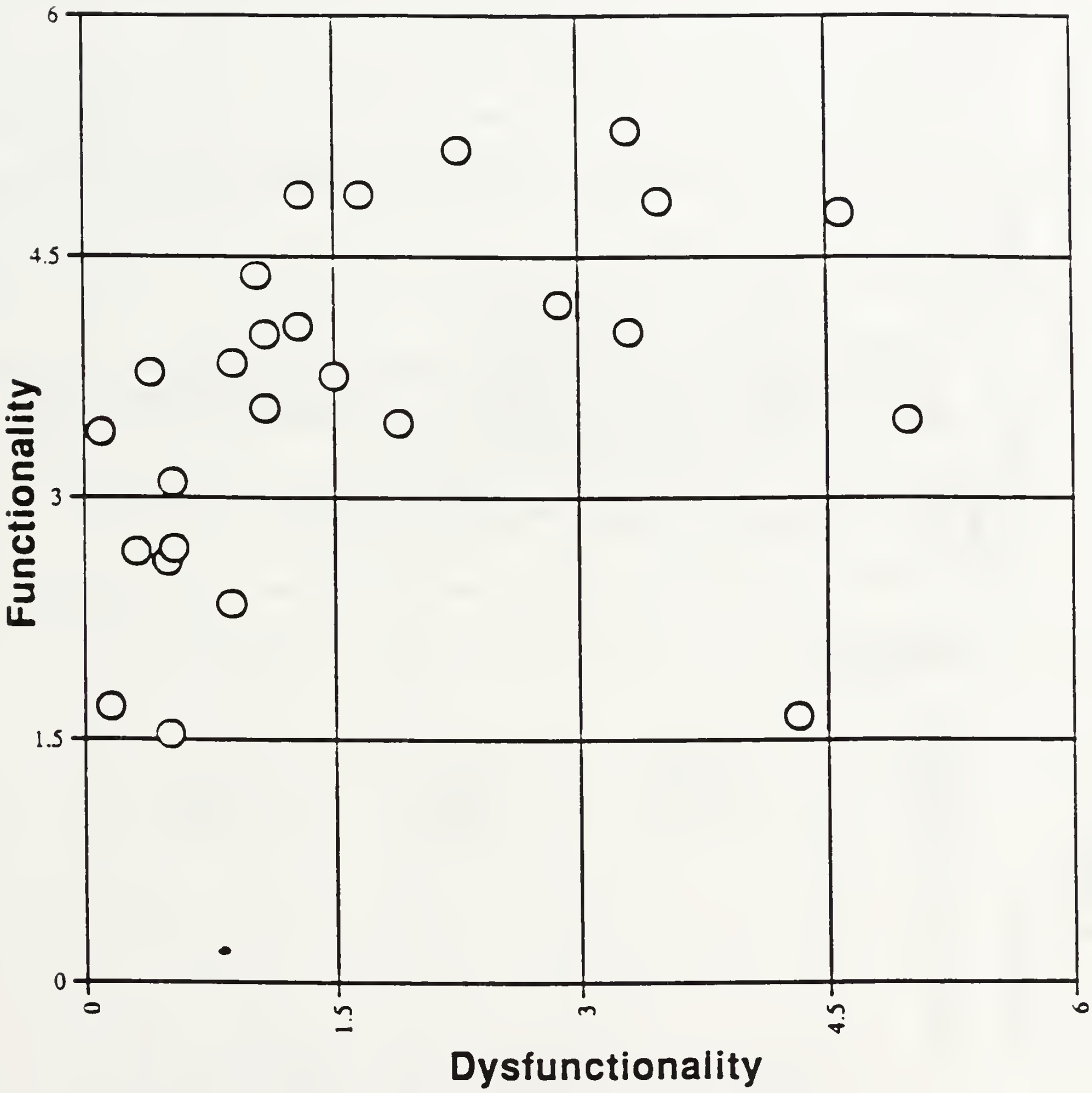
My Kano Questionnaire Interpretation



$$\text{Better} = \frac{A+O}{A+M+O+I} \times SSI$$

$$\text{Worse} = -\frac{M+O}{A+M+O+I} \times SSI$$

Kano Response Data



Title

Solutions Relative to the Datum

Kano Questions

Question number	CUSTOMER REQUIREMENT	Solution #1 Relative rating	Solution #1 Score	Solution #2 Relative rating	Solution #2 Score	Solution #3 Relative rating	Solution #3 Score	Solution #4 Relative rating	Solution #4 Score
9		0	0	0	0	0	0	0	0
13		+1	+4.8	0	0	+1	+4.8	0	0
23		+1	+1.6	+1	+1.6	0	0	+1	+1.6
14		+1	+4.8	NA		0	0	NA	
12		0	0	0	0	0	0	0	0
6		0	0	0	0	0	0	0	0
5		0	0	0	0	0	0	NA	
10		0	0	+1	+5.2	0	0	0	0
19		0	0	0	0	0	0	0	0
17		+1	+4.9	0	0	0	0	-1	-1.7
4		-1	-1.5	0	0	0	0	0	0
15		0	0	-1	-1.3	-1	-1.3	-1	-1.3
18		0	0	0	0	0	0	0	0
26		0	0	-1	-1.1	0	0	-1	-1.1
3		+1	+3.5	0	0	+1	+3.5	0	0
20		0	0	0	0	0	0	0	0
2		+1	+3.8	0	0	0	0	+1	+3.8
25		0	0	0	0	0	0	0	0
21		+1	+2.7	+1	+2.7	0	0	+1	+2.7
16		+1	+3.1	0	0	0	0	0	0
24		0	0	0	0	0	0	0	0
11		+1	+2.6	+1	+2.6	0	0	+1	+2.6
8		+1	+3.8	0	0	0	0	0	0
22		0	0	0	0	0	0	0	0
1		0	0	0	0	0	0	0	0
7		0	0	0	0	0	0	0	0
		+9	**+34.1**	**+2**	**+9.7**	**+1**	**+7.0**	**+1**	**+6.7**

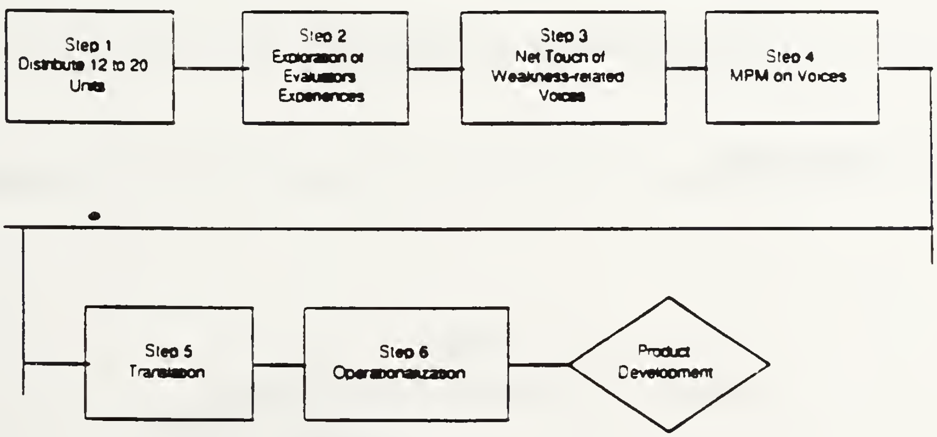
BOSE

The Use of Concept Engineering Techniques To Establish Fitness-for-Use For New Products

CE User's Group Meeting February 19, 1993

Situation:
Nearing the completion of new product development, prototypes are field-evaluated to test fitness-for-use

BOSE



CE User's Group Meeting February 19, 1993

BOSE

Step 1:
Distribute between 12 to 20 devices to evaluators

Purpose:
- Expose evaluator to product-under-test in their home environment
- Evaluator generates written notes regarding operation

CE User's Group Meeting February 19, 1993

BOSE

Apply results of Griffith & Hauser research

- How to choose evaluators?
  - von Hipple Lead User theory
- Evaluation Time
  - Acceleration of exposure to product-under-test
- Evaluator's Notetaking
  - Conscious recall of 80 percent of material lost within 24 hours

CE User's Group Meeting February 19, 1993

BOSE

Step 2:
Exploration

Purpose:
- Collect unfiltered information

CE User's Group Meeting February 19, 1993

Simple Discussion Guide

- What did you like the most?
- What did you like the least?
- If you were the designer, what would you change?

Use of Kawakita's Principles of Collecting Language Data

CE User's Group Meeting February 19, 1993

Step 3:
Extract Weakness-Related Voices/Net Touch

Purpose:
- Focus on areas not fit for customer use
- Organize data to streamline downstream processing

CE User's Group Meeting February 19, 1993

Step 4:
MPM on "must-be" issues

Purpose:
- Focus on "must-be" or "showstopper" issues (use Kano's dimensions)
- Develop a manageable set of issues

CE User's Group Meeting February 19, 1993

Step 5: Translation

Purpose

- Translate from evaluator's language into a form on which the Development Team can act
- Create unambiguous and unrestrictive requirement statements

Step 6: Operationally Define Requirements

Purpose

- Objectively define requirements
- Create system to assess performance alternatives

Opportunities For Improvement

- Write requirements for each voice. Then MPM requirements, not voices.
- Use Kano survey to weight/prioritize requirements.
- On CE projects, assess evaluator requirements versus CRs.

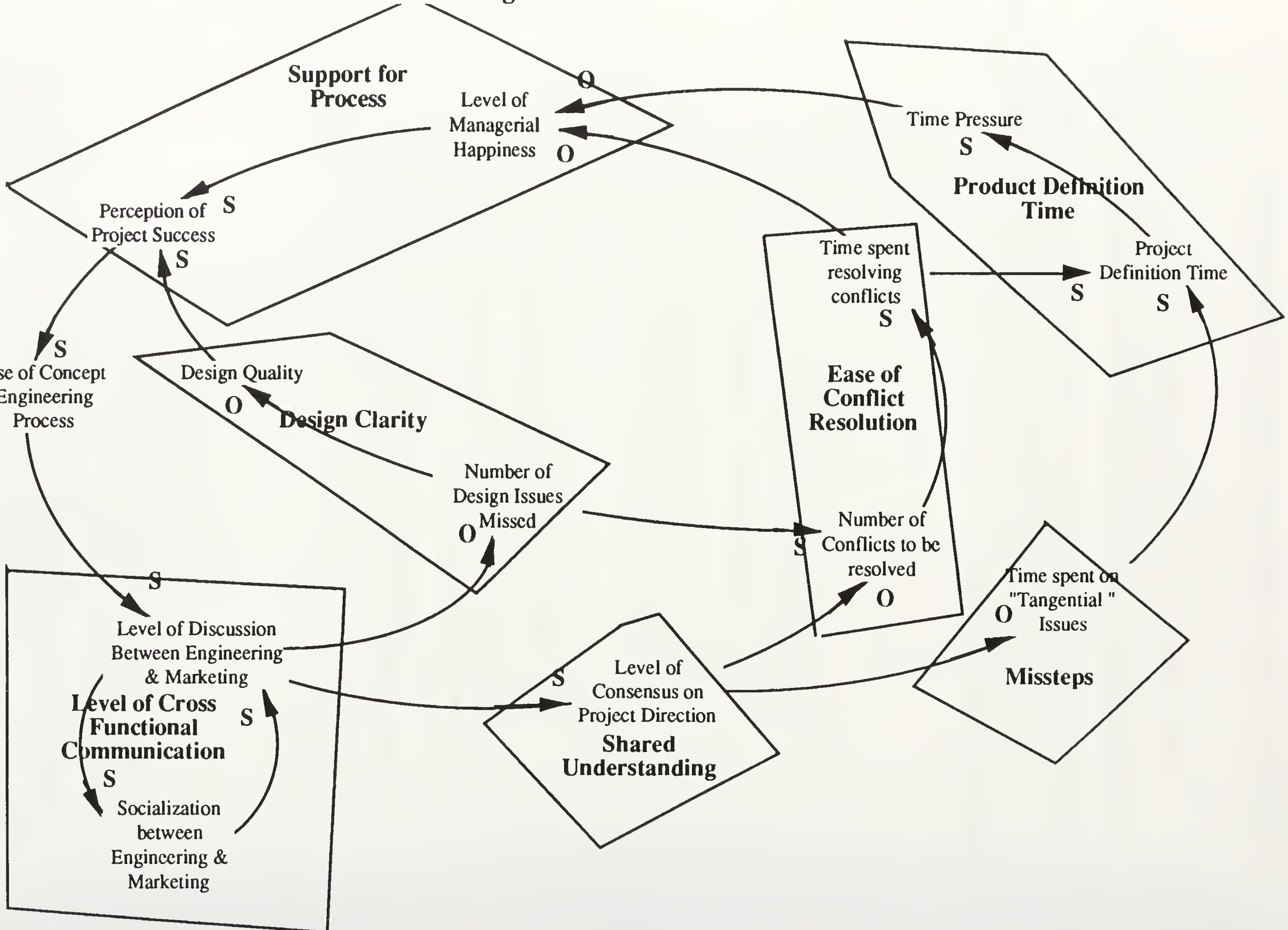
Assumptions

- Testing fitness-for-use employs "exploratory" research methods - not "confirmatory" methods.
- In simplest form, Development Team is capable of dimensioning issues as articulated in "voice" or raw data form.

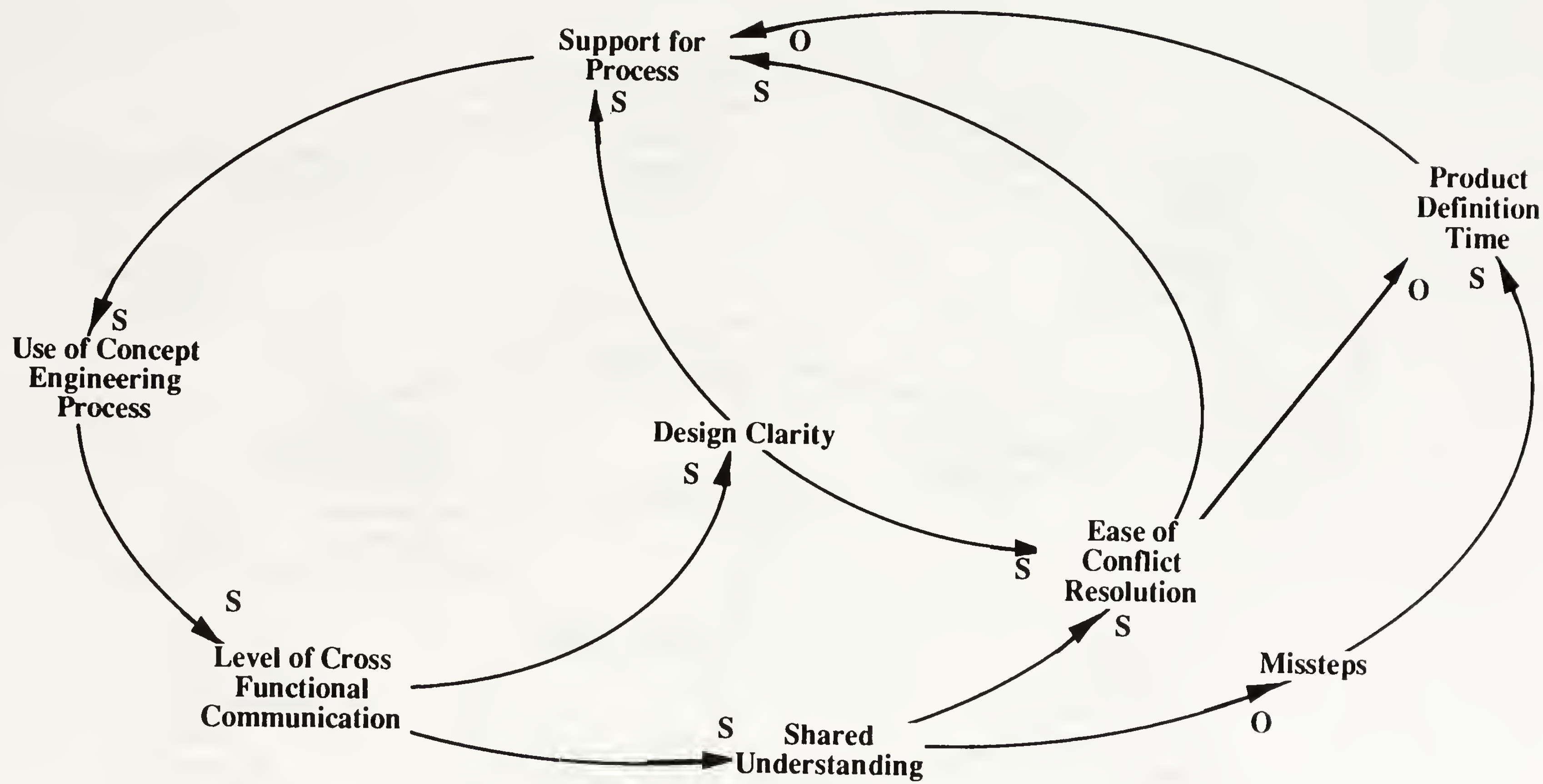
Appendix C: Inductive System Diagrams

The diagrams in Appendix C come from the Inductive System Diagram test conducted in the winter of 1992/1993. The first diagram in a series, i.e. Diagram #1.1, is the original diagram with the common variable names annotated. The second diagram, i.e. Diagram #1.2, is the revised diagram drawn with the common variables.

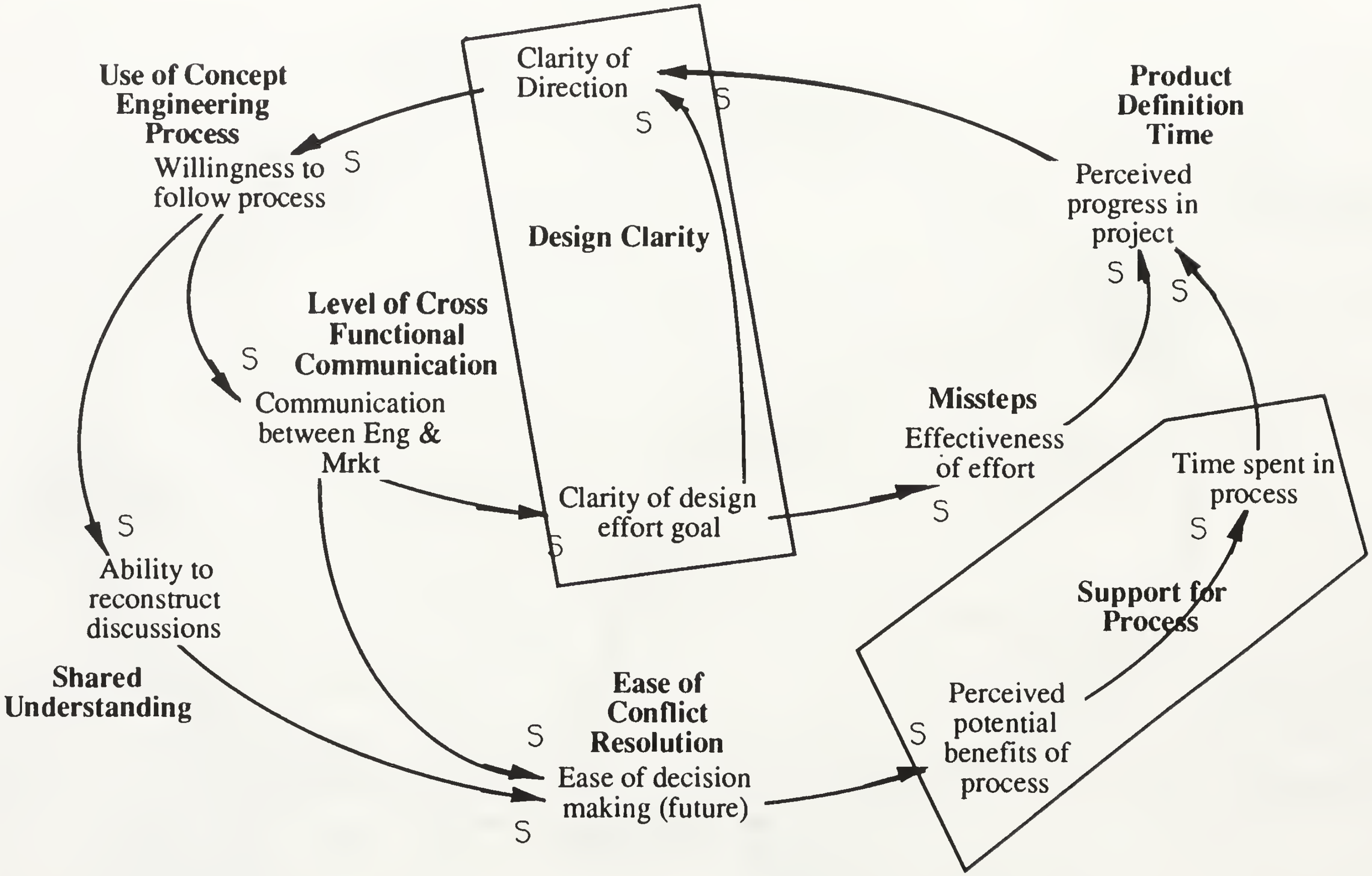
Inductive System Diagram Test (#2)
Diagram # 1.1



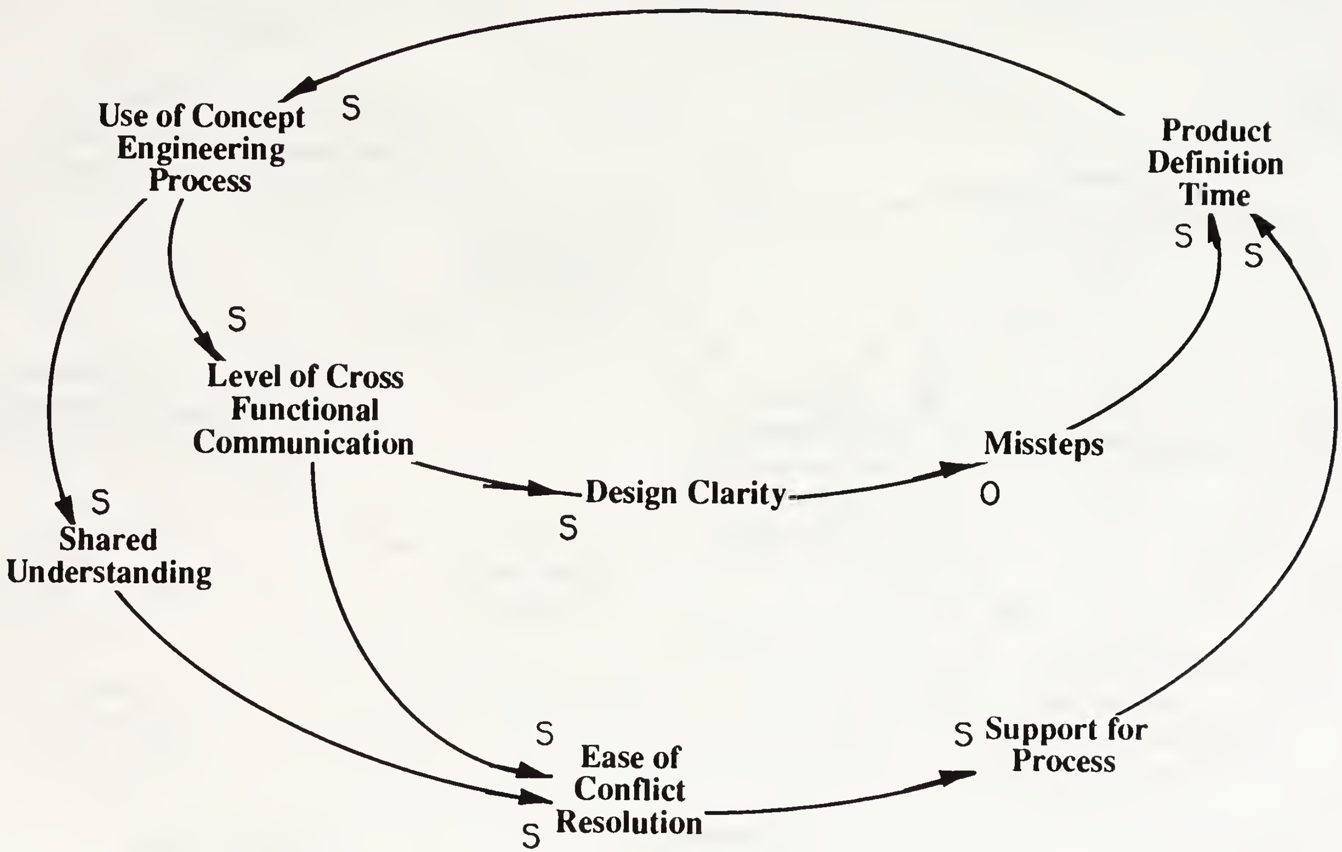
Inductive System Diagram Test (#2)
Diagram # 1.2



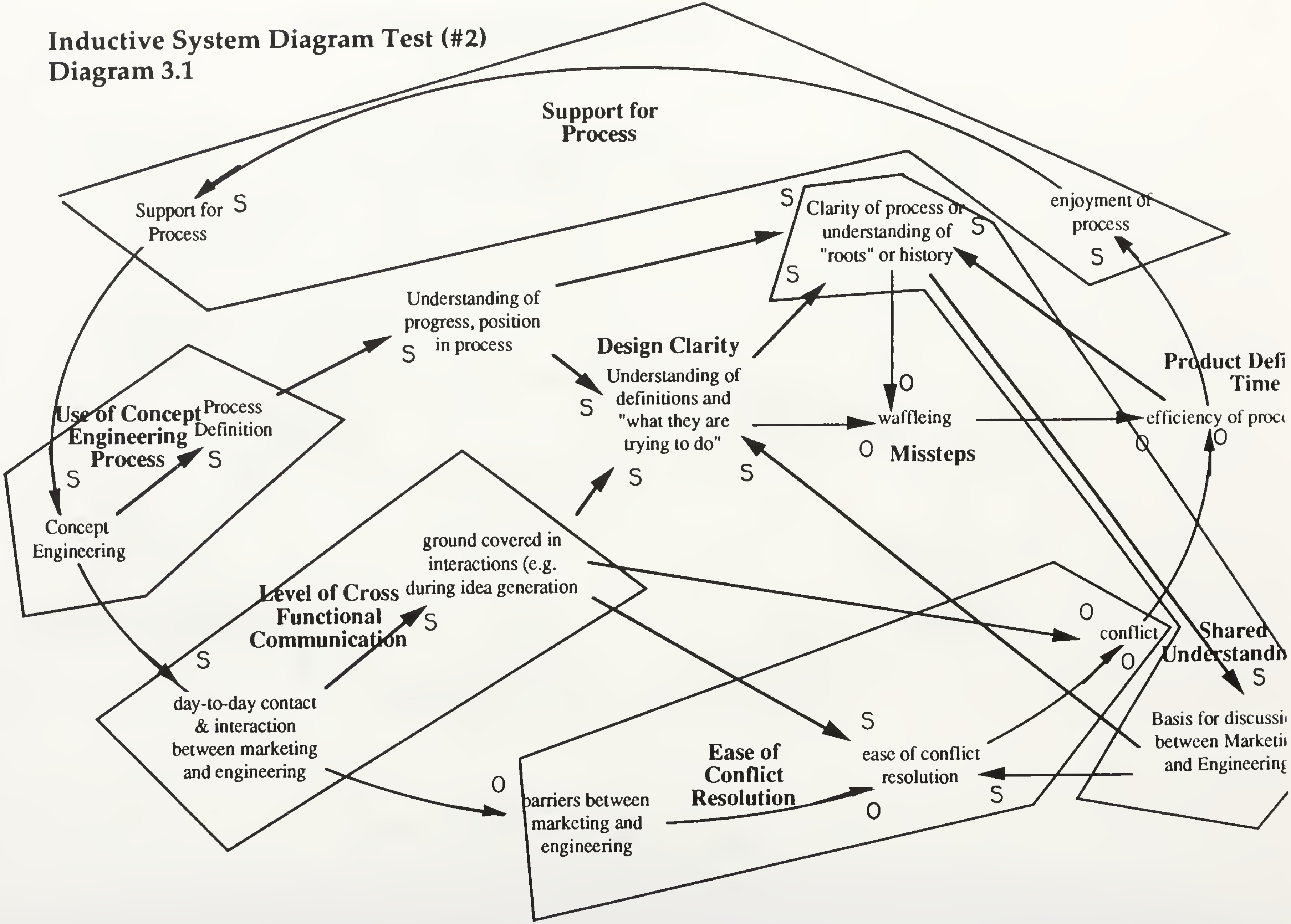
Inductive System Diagram Test (#2)
Diagram # 2.1



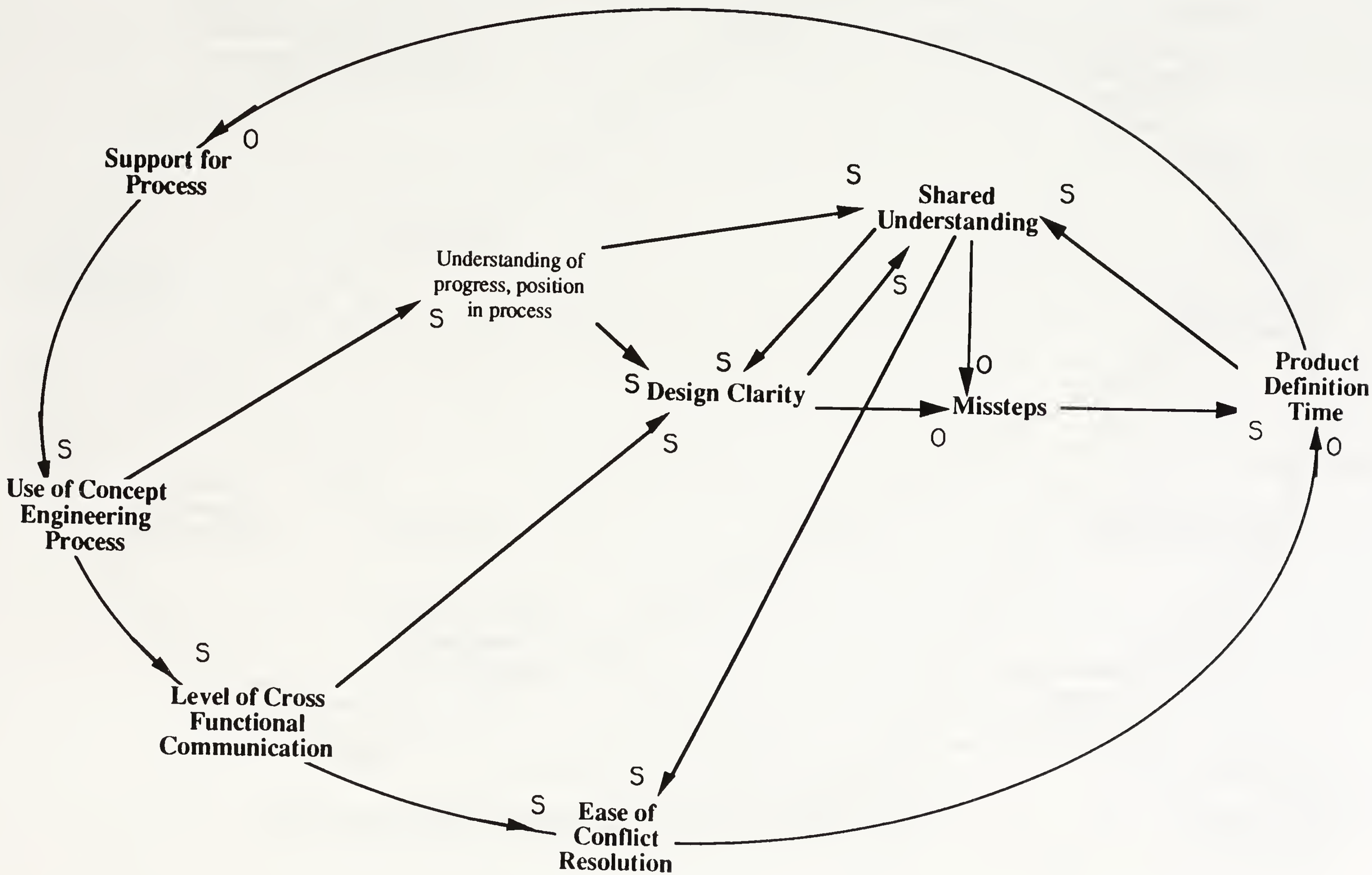
Inductive System Diagram Test (#2)
Diagram # 2.2



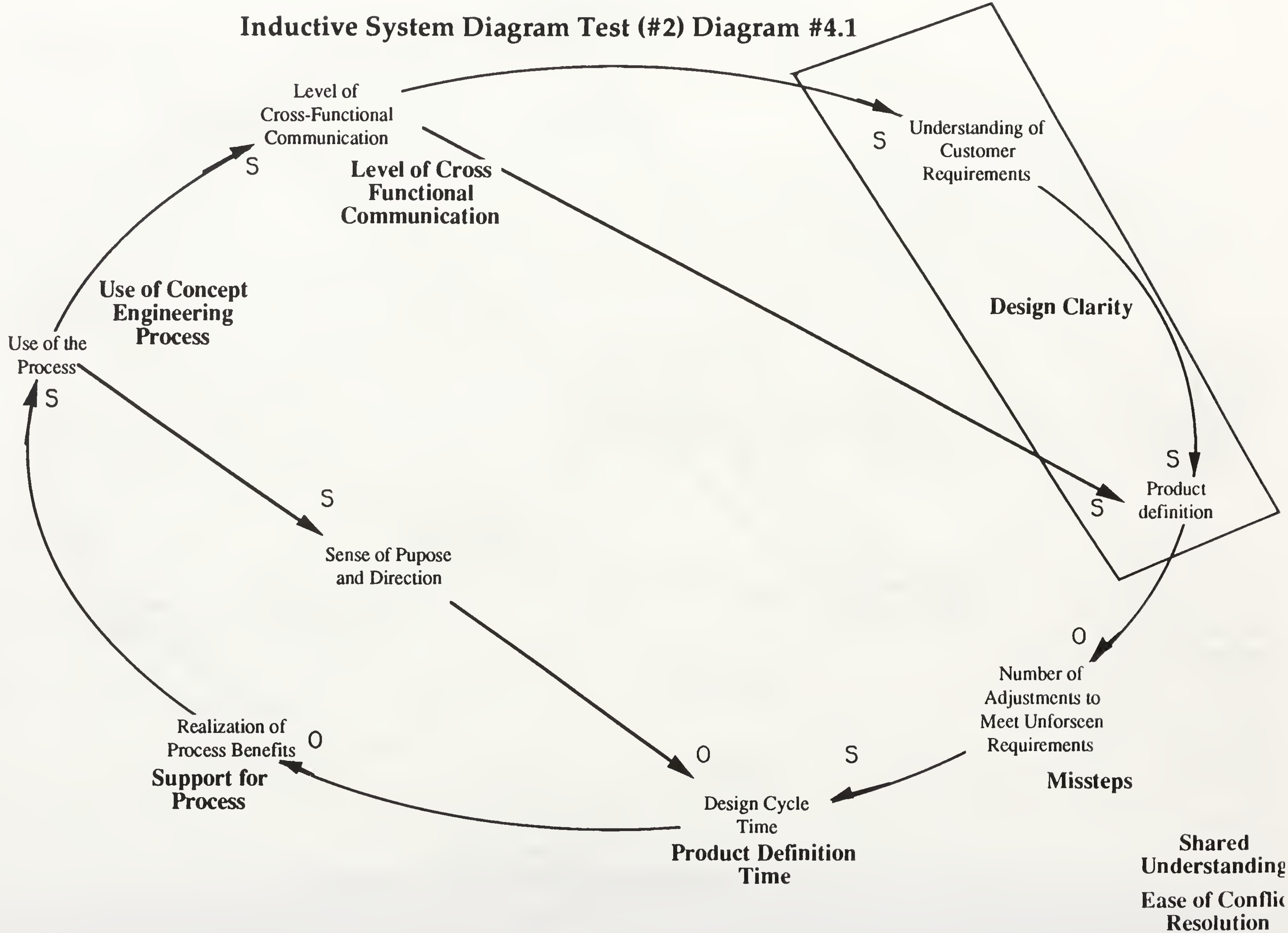
Inductive System Diagram Test (#2)
Diagram 3.1



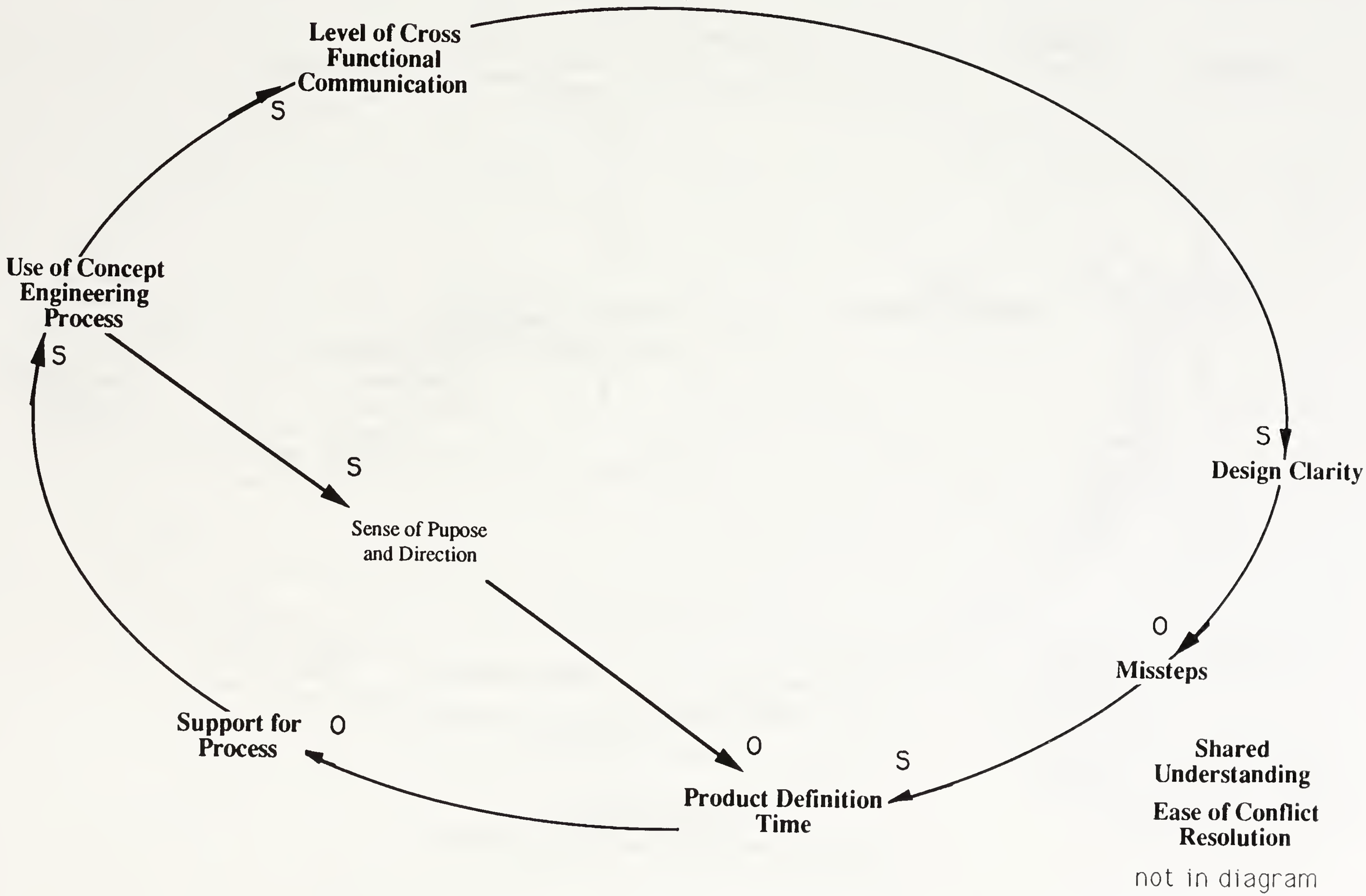
Inductive System Diagram Test (#2)
Diagram # 3.2



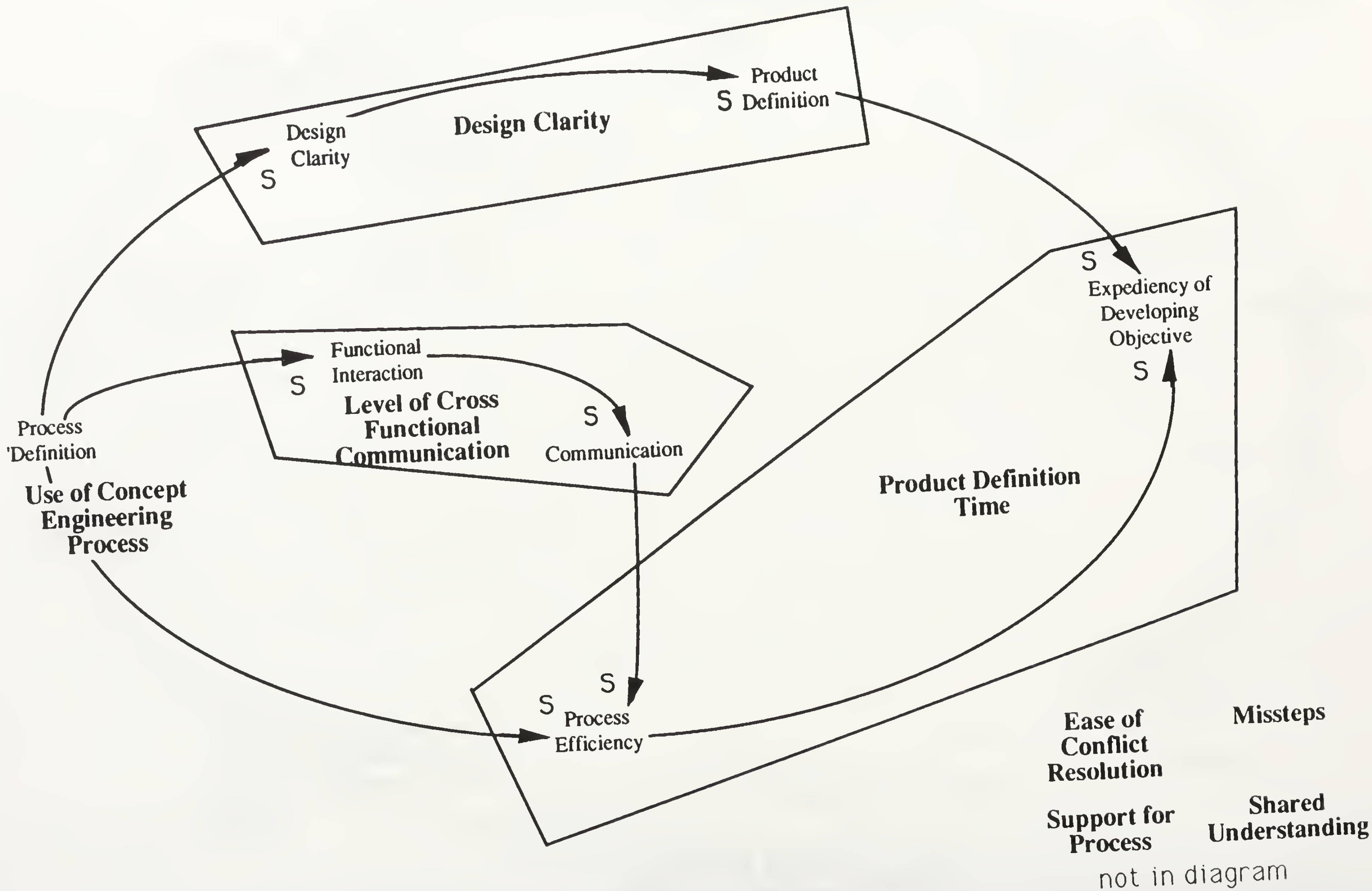
Inductive System Diagram Test (#2) Diagram #4.1



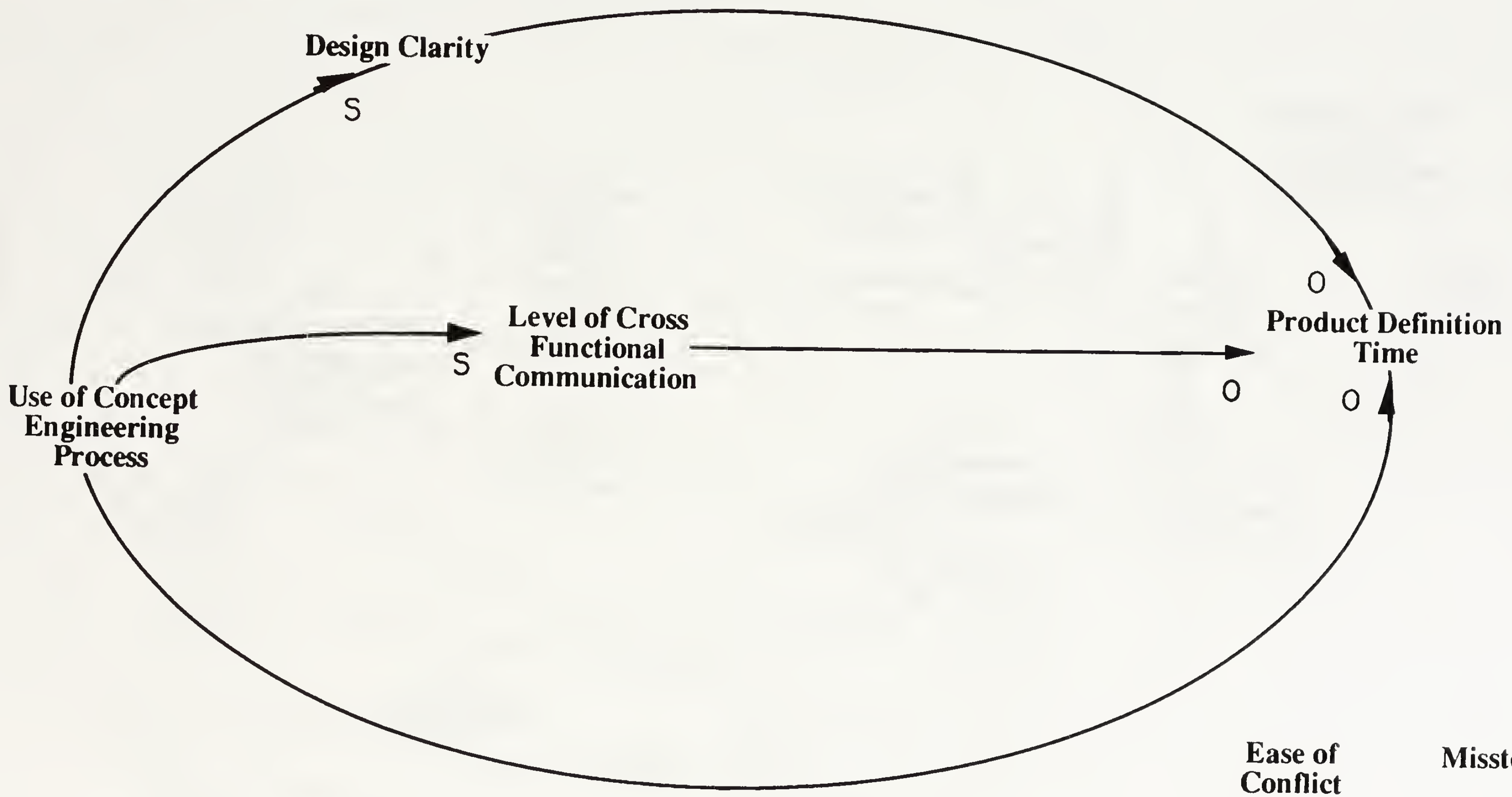
Inductive System Diagram Test (#2)
Diagram # 4.2



Inductive System Diagram Test (#2)
Diagram # 5.1



Inductive System Diagram Test (#2)
Diagram # 5.2



Ease of Conflict Resolution

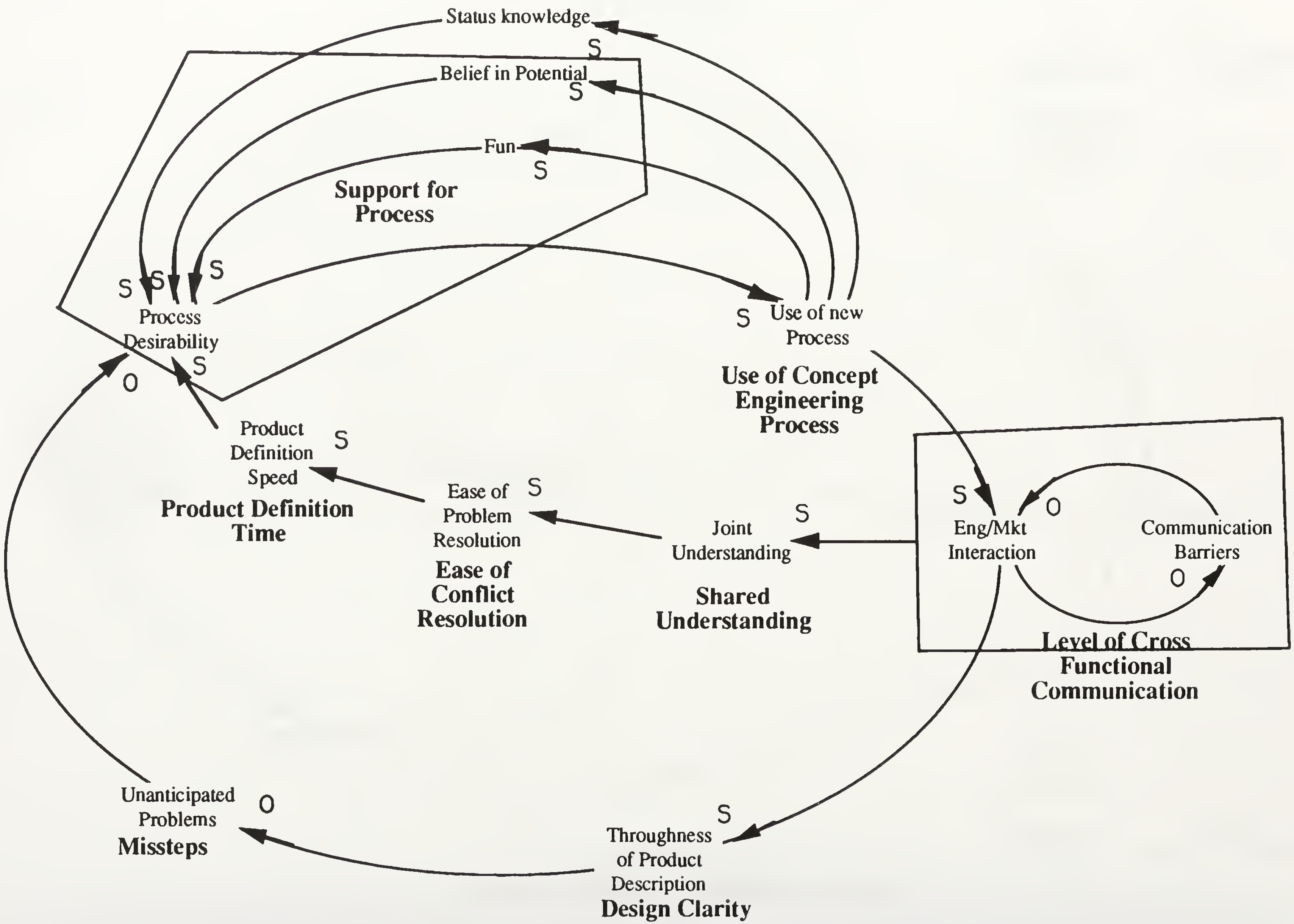
Missteps

Support for Process

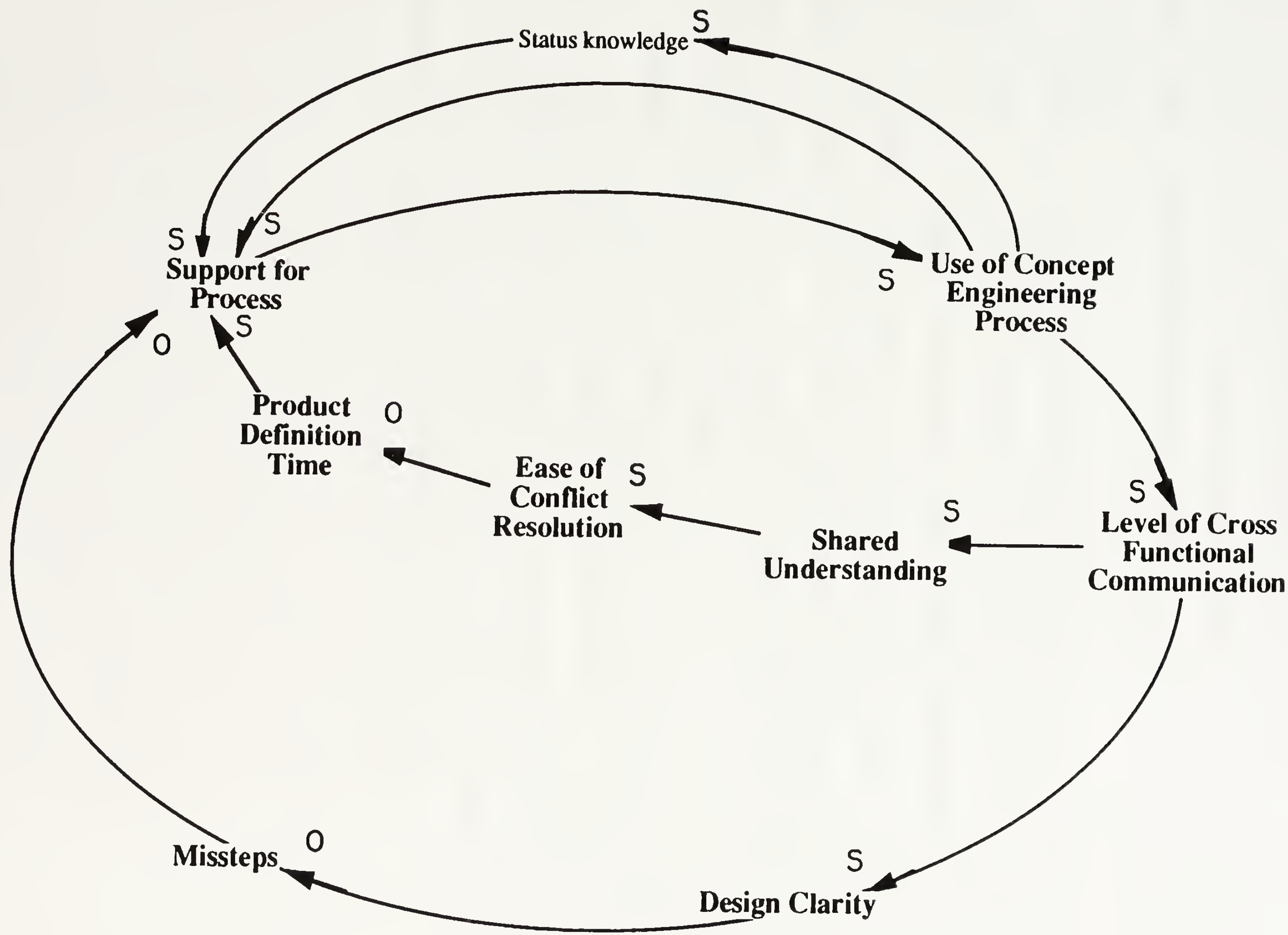
Shared Understanding

not in diagram

Inductive System Diagram Test (#2)
Diagram # 6.1



Inductive System Diagram Test (#2)
Diagram # 6.2



Appendix D: Selected KJ Diagrams

The KJ diagrams in Appendix D illustrate my approach to selective coding analysis for the variable Design Objective Clarity. A complete review of all field notes for each team was conducted and references which might be related to Design Objective Clarity were selected for consideration. As a result, all KJ data labels represent actual observations of, or statements by, product development team members.

The selected KJs represent each of the basic units of the comparative analysis. Team 1A came from company 1, used Concept Engineering, and exhibited time to MARKET orientation. Team 2A came from company 2, used Concept Engineering, and exhibited time to MARKET orientation. Team 2B came from company 2, did not use Concept Engineering, and exhibited TIME to market orientation. Team 3A came from company 3, used Concept Engineering, and exhibited TIME to market orientation.

The final KJ diagram represents a synthesis of the individual team KJ diagrams. The original data labels for this KJ were the first level grouping titles from the individual team KJ diagrams. These first level titles were then grouped and a second level title was prepared. The data labels shown on the diagram in this appendix are actually the second level titles from this analysis.

What did I observe about design objective clarity from team 1A?

Concept development is not emphasized

Design activities can change direction

- This process would have provided a clearer vision, a strategic path to the end itself
- Stop the number of dead ends. Stop paths with significant right turns and left turns

Concept development work is not recognized as valuable

I just have this continuum of fear or pressure is that knowing while I'm doing this there is no visible output

Concept development is not a priority activity

- Very difficult to get same sense of urgency from anyone for a product early in its gestation
- The development stage isn't the biggest thing on anyone's plate

Product definitions done by others are suspect

Engineers did not consider the marketing function to be competent

- Most of the people I've worked with from marketing I would fire immediately
- I go to marketing and say what are the things these people are looking for. Then I go to marketing and say these are the things you haven't considered

Product development specifications done by others not trusted

- The very fact I had face-to-face interviews it certainly helps to have confidence we are on the right path
- How do you know the researcher wrote what the customer said
- His (marketing rep) worst nightmare is that a bunch of engineers are selecting the product specs

Analysis promotes confidence

Documented analysis promotes management support

Documented audit trails reduce management concerns

- If the data is really good, and well-presented, the credibility is up and the attacks are down
- By documenting a trail, perhaps you head off some of the restrictions that get imposed on you

Senior executives can be convinced with documented analysis

- I have high confidence and better ability to sell to executive committee because the process is self-documenting
- Concept selection process provides credibility by verifying intuitive concept to someone (PRB) who doesn't understand what is going on

Systematic analysis promotes confidence

Confirmation of personal perspective with customer data increases confidence

- Validation of what I thought was right for the market is a net gain
- After the interviews the data is somewhat different although for the most part I could have put down the parameters a couple of months ago. Now I have higher confidence

Fear is reduced when decisions can be supported confidently

- We will have exhausted every arguement they (PRB) can bring before us I would no longer feel nervous
- If we follow a process which presents objective data, you don't have anything to hide from. You have enough data to support your case

Maybe I'm spoiled by this process because it has become intuitive to me. A3F solution led to A4F

Confidence in results

- I am willing to sign on the dotted line as an internal spec
- This absolute belief was unshakable, no one could knock me off
- I get the warm and fuzzy feeling

Contextual awareness improves understanding

Customer contact clarifies requirements

Requirement interpretation differences can be settled by reviewing customer context

- They began to discuss what a label meant and went back to the customer voice and rewrote the label
- Disexplaining a grouping. Others are explaining their versions. B wants to know the context of the interview

Customer exposure influences designer actions

- When you go and get toe-to-toe with customer it is dramatically different than being in the plant
- All the stuff worked for me because I was continually feeling for the customer; every input modified what I was doing
- I would dearly have loved to have one of the designers involved to get an appreciation of why you're putting this here or that there to get exposure to customer focus

Individuals determine design outcomes

Designers must make tradeoffs

Designers cannot do everything

Designers are constrained by factors outside their control

However, can't shoehorn a requirement into a box that doesn't fit

I get constrained by materials selection I don't have control over, and design constraints I don't have control over

Designers want to focus on the vital few requirements

Try to weed out as many possibilities as I can early

We can't do everything so let's focus on the critical few

B&B look at the remaining labels and state: "I'm not going to vote for anymore; I'd rather say 21 than go 24 and have some bogus

Designers want to know relative requirement importance

I have to know which tradeoff buys more than It loses

That's where I need the input that tells me where I need the emphasis

Designers need to understand how factors interact

Designers work backwards from an image of the finished product

I have to get the big picture first. I have to know that it feels right first

I see the finished product and then I see myself using it and then I write the specs

Features are so interrelated so I could not do it in a vacuum

Committed people make positive progress

Commitment to design objectives promotes design realization

Post program approved then run in automatic, hard work but people already know what to do and want to do it

It is safe now. Once it is defined and concensus is built it will stay. I don't have to worry that some mutant child will appear in its place

Passionate participants ensure the work gets done

They have ownership. They don't want to let other people down

I think that where there is passion there is ownership and those two combined; when they exist in the same group of people and the team encounters problems and difficulties they don't last

Every single day that passion enabled us to come in and fight the good fight, to do the things that needed to be done

Individual bias can determine the design objectives

Senior managers can dictate product attributes

I can see the Japanese country manager coming up with a requirement which is completely out of phase

The top executive threw a product idea out on the table and it was assumed as a mandate

The chairman made a decision on the spot to include x

Personal agendas can be pushed during design activities

We've had people who lost a contract because they couldn't do a certain thing...Takes 90% of emphasis, but the missing item may be only 1% of customers

We used to make it exactly the way we wnated before this

When pushing the marketing rep for the customer voice he stated, "I don't really have a voice for that, I made it up because I think it's important."

Process participation promotes understanding

Discussions are used to clarify written statements

There were several different discussions about what the real requirement was; eventually there was a concensus of the requirements' meaning

During Image label final round MPM selectees discussed what they saw in the labels they select

Someone that has buyin understands the program, understands the requirements, understands the how and why, and can explain to other people horizontally or vertically

Participation in the process builds understanding

This whole process, by going through, we have generated separately, we all converge on the solution

This process allows us all to see the data and gain buyin

The outcomes of the events we have been through together, excluding the CRKJ were surprising. Now the results of the CRKJ are not surprising to me

March 5, 1993
Bedford, MA
Gary Burchill

What did I observe about design objective clarity from team 2A?

Requirement statements cannot stand alone

Requirement statements needed clarification

Placing requirement statements in context of original voice can clarify intent

During metric development B goes back to a worksheet and reads the original voice

We will come across so many decision points—self-documentation allows us to go back to where and what customers said

MS reads a label, S makes a comment, MT says "No, it means..." MB states what he thinks it means

Metric development clarified the intent of some requirements

During metric development the team conversations appear to be directed to clarifying technical characteristics of the requirement

J: I am beginning to change my mind on the ambiguity rating we gave this requirement. When we look at the metric it is not at all ambiguous what we want to do

There are tight trade-offs, severe limits to what you can do. Prioritizing those is mainly what you get from the customer

Focus determines effort

Limited focus concentrates effort

Designers want to focus on the vital few

B is last to select. Finally he states, "Nah, I don't want any of these" and walks away without selecting anything

During the first round of CR MPM, MT states, "I like all of these but I have to be selective

Discrete bytes of information are easier to process

It seems easier to be able to capture bytes of information and carry that through the process rather than a huge story board

Breaking it down into individual pieces it was important to me to separate every idea on the paper that allowed us to focus reflection on each idea

Clear objectives direct designer efforts effectively

Understanding design objectives clarifies what to work on

A consequence of really understanding customer requirements is you know what is important and what is not important

They will know what to solve and what not to solve

Prioritized requirements tell you what is good enough, where you have to put efforts, or where you can compromise

Designers won't get off on a tangent spending a week or two chasing something they think is neat, they will be more effective

Unclear design objectives reduce confidence

A consequence of unclear objectives is you second guess the project during development

A consequence of unclear objectives is you have a team which questions Itself

Understanding is based on preceding experiences

Product definition activities build on prior efforts

Ideas are connected to the results of previous work

MS is reading his label to the group and walks over to the Image KJ and points out the connection to the idea

During idea generating, B sits in front of the Quality Chart and alternates between looking at the QC and looking at the panel; periodically writing new ideas

By knowing the roots they are going to know how we got to where we are in the product definition

Requirements were clearly linked to customer voices

I still find the power to be able to link one voice to one image to a key item to a requirement

When I use logical/systematic thinking in this I think here is what he said and here is the requirement which matches what he said

Exposure builds support

Senior management clearly demonstrated support for the team

The GM starts the IKJ session by telling the team his corporate annual hoshin dealt with creating value through VoC

When it was mentioned that meal tickets were available it brought surprise and satisfaction from several team members

Process participation builds process confidence

The people bitching about the time are not the people on the team

When we got into the room there was built-in credibility because the person who is processing the information is witnessing data collection

The existence of a common background eases conflict resolution

They (mkting. & eng.) are both going to know where the definitions came from and that will make the resolution of conflict a lot easier

Since we have gone through this process digesting requirements and looking at marketing perspective and we came to consensus, we can eliminate trivial arguments during design

Systematic analysis is thorough

The team took time to be thorough

MS states, "Ok, everyone happy with this?"; MT says, "No, we need to think about this one for a minute."

Some suggestions from the team move on as the group appears to be addressed elsewhere. MS suggests they reflect on the group's strengths for new ideas. Six ideas get generated

During the check for omission, MT states "Ohhh, that one is not captured anywhere else, put it up there

Systematic analysis reduces downstream surprises

We have covered so much it will be hard to think we haven't thought about something

Once we decide what we are going to do there shouldn't be any surprises

I sense a more direct path to end product—not missing things that will come back to haunt you later

Awareness of use environment can influence design

Actual experiences carry credibility

Stories of real experiences are used to clarify points of discussion

MT answers a clarification question with a reference to an existing part and the problems with it

An idea comes up about second sourcing: MB tells a story about a competition, MS tells a story about a customer

The second item of credibility is we have an identified group of people when or if push comes to shove we can go back to

Requirements anchored in customer experiences have credibility

As a team member, it is credibility that the ideas from others were born from a customer need

In answer a senior manager question on performance spec the senior engineer answers with "Some of the people we talked to…"senior manager nods his head

Customers view the designed part in a broader context

One level up perspective—not looking at my piece but seeing how my piece fits in

Customers have their own priorities; my part is only one of many things the customer has to worry about

The factors that determine whether a product is successful are so different product to product you have to adapt

Designers put themselves first

Designers typically make decisions from their vantage point

Designers don't always consider the implications of their decisions on others

It used to be our goal was to just meet the basic specs without worrying about what other people do

You make an arbitrary choice during design and find out later it's much harder (for others to deal with)

We used to do product definition by the-seat-of-the-pants; Judge info from customer from your perspective which tends to be biased

Designers typically discount inputs from non-technical people

We get sales' input in design process we tend to invalidate them or see this as not as important as our technical insight

Normally, you take a young marketer and send him out and say go talk to customers and they come back and tell the engineers what the customers want and the engineers say he doesn't know what he's talking about

Traditional development can lose sight of customer requirements

Dominant individuals can dictate design objectives

Last project we worked on we had authoritarian eng. manager who told us exactly what to do whether we wanted to or not

The biggest dilemma in the past is that a few very strong characters defined the product whether it was fine or not

During development, some requirements can be abandoned

All too often you put blinders on, getting in a rut attacking one piece of the problem and letting other aspects slide

We used to set the requirement (solution) and then go off and try to do it. If we could not do it, we would make decisions that it must not be that important if we cannot do it

Traditional approach to capturing customer comments is inefficient

Led me to believe that trying to capture what customer said with a one-liner every few minutes and looking a week later, ridiculously inefficient

Out capture of the (customers) answers is normally sporadic and wee lose a lot of these answers

Designers find it difficult to change existing designs

Once you design it, it's hard to change it, there are things you can do up front

Typically a designer starts working and it's based on his or her ideas. Not until you do a review do you get other ideas; it's too late to make changes then

What have I observes about design objective clarity from Team 2B?

Customers had minimal influence on the design objective

The design was influenced by factors other than customers

The engineer was focused on technical considerations

Understanding technical trade-offs increased the engineer's confidence

- In other products I didn't have everything completely defined but I was confident how to make the trade-off
- One cause of confidence is being able to draw a strong correlation between your hand calculations and your simulations

The engineer viewed the performance specs as a by-product, not objective of the design

- E's want to say this is what I want to do and whatever the specs are is what the specs are
- M: It looks like we are worse than the competition E: I'm not sure what you are getting at E: Well, shouldn't we be better than they are? E: I guess it doesn't concern me because . M: I think technical requirements are pretty comprehensive. What we need are target specs on what the part should do E: What the part can do or what we think it can do?

The engineer wanted to begin the design discussion with technical issues

- Twenty minutes into first meeting the engineer states "Do you want to get down to current issues?"
- At first meeting a discussion developed over the agenda. The marketeer wanted to discuss markets and the engineer product architecture

Design objectives were influenced by environmental influences

Target markets were determined from reviewing the companies strategic market analysis

- At first meeting the marketing rep outlines market segments and key product performance specs for each
- After reviewing the group's strategy document (created three months earlier) a subset of market was targeted

Design objectives are influenced by competitive products

- E: I've got some competitor parts M: I'd think it would be worthwhile to look at those before we finalize the design
- We decide what type of product by looking at competitive products, what holes are out there

Company employees, without the teams experience, can influence the design

Other designers are a primary influence on the engineer

- The other cause of confidence is to be in touch with other designers so you know what is going on with them to get a reaction from them
- There are a few other people I work around who have preceded me in this process, so I have been talking to them and simulating
- Other designers are my first influence

Product attributes can be determined by people in power who lack detailed understanding

- At PRB. A lengthy discussion about reviewing C and repositioning as a B
- M: Do you think you need to publish a little memo? People have different ideas about things most of which are shooting from the hip

The marketing function didn't transfer customer insight effectively

The marketing rep was reluctant to share customer source data

The marketing rep was reluctant to give the engineer access to customer contacts

- E: Perhaps I'll talk to a couple of customers M: I'll give you the name and numbers of two customers
- I sense M is getting frustrated that E wants to talk directly to customers instead of relying on his data

The marketing rep did not share his actual notes from customer visits with the engineer

- During a discussion regarding a performance spec M states: "We should probably look at my notes in detail," but made no attempt to retrieve them
- Marketing rep mentions his intent to review notes from a customer's identified with the target segment
- M: So from here do you want to look at C on CPB? E: Can we just see which customers are doing what? If we have time M: I don't have any notes with me

Marketing reports contained less information than desired by the engineer

Direct customer contact provides the engineer more information than marketing reports

- Talking to customers you also get images that make it feel real. Having a customer say 'yeah, that will be great' rather than some number from a marketing chart
- By focusing on the customer you get some of the finer details you can't get from marketing
- M: I can go through my notes and look for what you want. What do you want? E: I kind of want everything you've got

Customer contact promotes engineer's sense of connection with actual users

- Another is to feel more connected to the end application you know the name of someone who is using it
- I want to know months ahead of time I am going to be sending this to someone who will be giving me good comments
- After talking to a certain number of customers you are comfortable, don't know if it's 10, 20, or 30, even if I have two customers I can talk to that would make me feel better

Early access to an actual design was important to the team

The designer wanted an actual design prior to discussions with others

The engineer wanted an actual design in order to talk to customers about trade-offs

- After having done simulations I can say to a customer 'This is what I'm doing' and they can say 'do x,' and I can say 'I can do x, but it will cost you y'
- Engineer asks to speaks directly to customers because he is worried about technical trade-offs
- The last source of confidence is to talk to customers after you have a product definition

An actual design was the basis for discussions with other designers

- You need to be very quick to get something up on the screen, and that becomes a good device for talking to other designers
- You learn around here (company Z) what gets a response and interest is having a schematic

The team wanted to start design activities quickly

The marketing rep pushed to shorten the product definition time

- M proposes they have 75% defined at the next (second) meeting
- R: I'd say about a week to get the parts, a week to analyze the parts and then a week to respond if I need to M: Huhhh!
- M: At the next meeting we should be very close to a decision. I am a very impatient man

The engineer wanted to start design activities prior to having a complete understanding

- What I want is to talk to 2 or 3 people who have experience briefly to know what they think, but I want to get going
- In the initial stage, you don't want to get hung upon all of the goals
- You just have to jump in and hang on

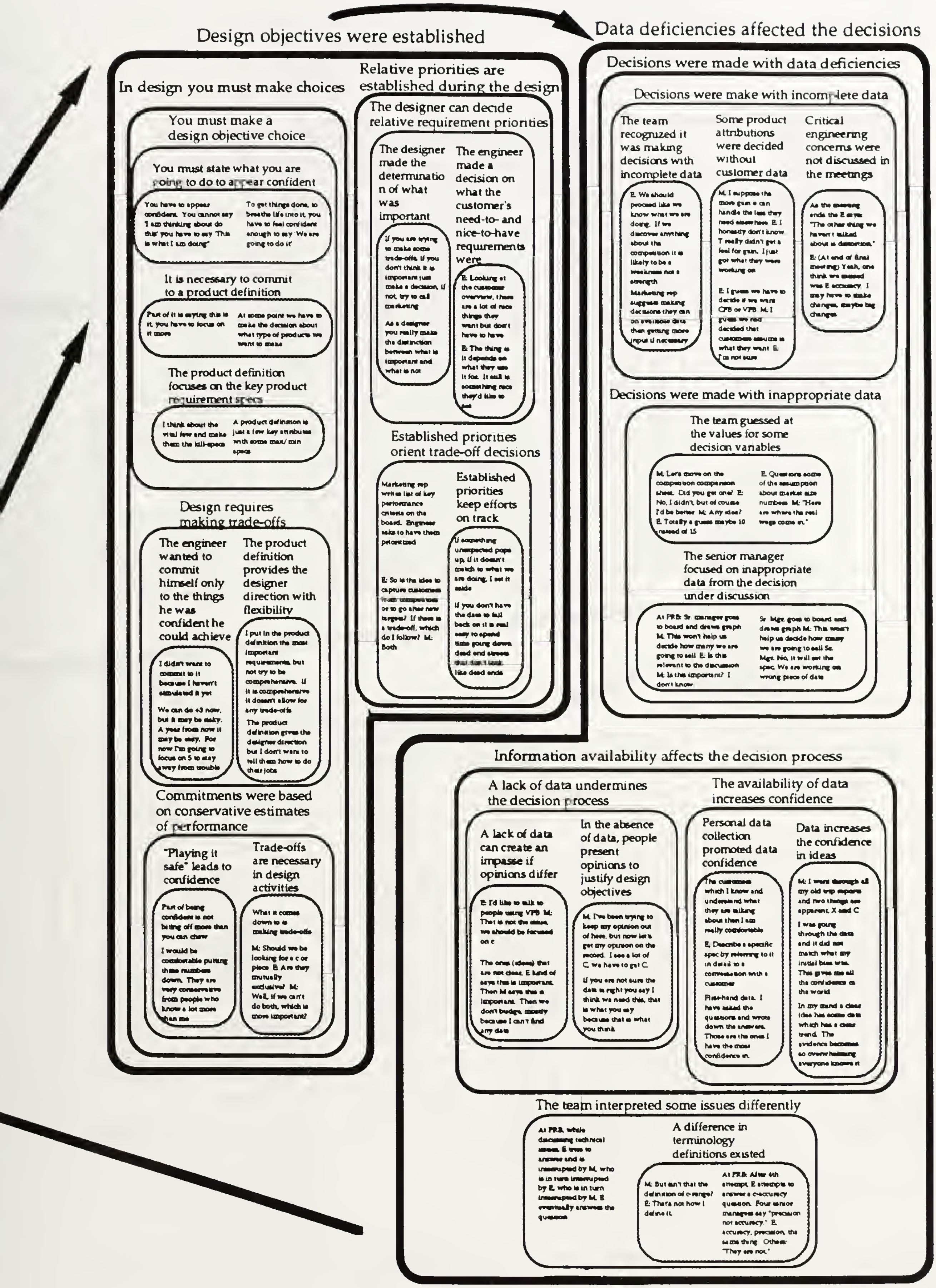
The proposed design objective was not compelling

The team acknowledged the decisions could change downstream

- You have to make some dead end streets, take some wrong turns, if not, something is wrong
- Realize you can always go back and change
- E: When you say specs what do you want? M: I need target specs; they will change—yes, hopefully not much

The senior management group was not committed to the proposed product definition

- At PRB, a lengthy discussion about substitution which would determine the need for amount product
- At PRB, senior engineer questions 50% market share as the 4th entry into the market
- At PRB, 1 of 3 senior E want to sign approval. 1 of 3 senior E says: "Let's go; we have wasted enough time here," as he signs the approval



March 3, 1993
MIT
Gary Burchill

What did I learn about design objectives clarity from team 3A?

Individuals did not identify themselves with team results

Process participation builds contextual connections

Individuals had agendas unrelated to team efforts

Individuals tried to reduce their exposure

I never wanted to put things down that I couldn't deliver, didn't want to get backed into a corner

People right now are doing anything to keep their jobs—includin g keeping their mouths shut, doing what management says, whether it is right or wrong

R had 8 black labels completed. Everyone else was grouping. L (noticing) "How can you be writing blues without looking at the group?"

The team felt senior managers would dictate solutions without reference to teams effort

If we get Tony involved he will want things certain ways. that whole week of CE stuff will be wasted.

If you throw up solutions now and get a relatively strong response, we could end up designing the system in that room, and they are not on the team!

Agreement to move on did not mean agreement with results

Agreement to proceed does not mean agreement with prior decision

You get a committee solution again. It's the least common denominator...people don't see anything wrong, but they are not particularly happy with it either

Discussion of this first group took 20 minutes. People were discussing combinations with labels outside the group, and labels were shuffled around the board to create hypothetical groupings. No one seemed particularly satisfied with group or title when they moved on

W complains he cannot think so fast. He thinks the pace threatens "reproducibil ity"

Image KJ is easier because no emotional attachment, as in CRKJ

The scope of the project was not clearly established at the beginning

We fluctuated as to whether we wanted to develop a whole product or just a package

Also there was confusion originally whether we were talking about Aries charts or the entire Aries system

Common understanding facilitates group interactions

Common experiences build better relationships

I think the advantages, despite the continuity and involvement, are having a group of people who share some common experience

If develop-ment and mrkt hear more of the same stuff from customers it has to build a better working relationship

Common perspectives diminish arguments

What I think we need to do is get us all in a room and discuss them. Things that don't make any sense, we would agree to let go.

I kind of saw it as we spent a lot of time on the up front end part. I though we would have less things to argue about later

Process participation provides more information than process output documentation

Documenta tion lacks the affective qualities of interactions

It is docu-mented, but it is still not the same; it is not like bringing one team member on

We have lost some people who did good visits. We have lost what they heard, what the customer did, all we have is their notes

Sometimes I wonder about this. When you hear something from the customer it makes sense. If you extract it to the yellow stickie, it's a problem

Turnover created inconsistent levels of background knowledge

With turnover we will have backwards movement because we will have big difficulties in getting consistent thinking on the team

New people will not be as grounded in the customer requirement background

Management did not support the team

Team members assignments were disruptive

Interview teams had skill deficiencies

2 of the 4 core team members who did interviews did no shallow water swims

The core team came up with a list of questions we were to ask on our visits. My personal experience was that I didn't use it

My first clue was when the interviewer handed me a set of his noted because he wasn't sure the note taker was taking good notes

Assignments to the team were made at the last minute

2 of 6 core team members who did crunch work did no interviews

Won't really know until the 15th (IKJ) as to who is on the core team

It was almost a fluke that I was there at the training. I was a substitute at the last minute. I was not clear when I went what my role was

The team experienced massive turnover

Every engineer assigned to the team either transferred, quit, or was fired

5 of the 6 people participating in stages 2, 3, and 4 did not participate in stage 5

The team perceived a lack of management commitment

To us, gaining a better understanding of the customer's problem is important, but to them (PRB) so what

At this point it is real clear other companies have much more management commitment than we have

Management actions created delays

Engineering personnel were committed to other projects

This didn't get the attention particularly of engineers because they are tied up on other projects

If I have to take engineers out (VoC visits) we are so resource constrained it means skipping a project

Management created a delay of several months

There was a delay (Jan to May) in the interview process

It is mainly the mixed message of thinking we had a clear guidance and then being told to stop

Customer's context clarifies requirements

Abstracted statements can create divergent interpretations

Higher levels of abstraction reduce clarity of original intent

I don't think we can get it to a "+" or "-" question. It's too high a level of abstraction

The higher we go, the more we deal with semantic problems, and we redefine the things that already have meaning. You can't change the Oxford dictionary.

A CR substantially rewritten during CRKJ label scrubbing was a source of frustration (vagueness) in metric and Kano development

A statement can be interpreted in different ways by different people

I asked, "What is guidance? An on-line help function?" They replied that it was not, that it was information on how to analyze data, sort of an expert system

A discussion begins. This requirement has somewhat different meaning to the participants

He says, "I understand the words, but I don't understand what they are saying" A discussion arises to further refine the title

Requirements anchored in context are clearer

Customer statements without context decreases requirement understanding

When you're looking at images of VoC, and getting conclusions in requirements is the only method to clearly define a product

When you do VoC, and the customer says, "I like x," if you don't investigate, you don't know what the message means

Very often the discussions entered semantics problems, not the facts. That's because the facts weren't clear

References to customer context resolved debates regarding requirement understanding/ meaning

References to experience in customer's environment was used to clarify requirement and develop metric

Some confusion arose over a label. Some participants offered their interpretation. L located and reread the context. this settled the matter and discussion moved to the next label

The customer's starting point is a very concrete way that a thing should happen. Ours is always a very general method

Individuals had an understanding of only a subset of the total requirements

An individual had a limited ability to explain all group decisions

I found that when it was someone else's idea, it was impossible for me to say what it means

When the consultant goes away, then I am the only person left. I won't have a lot of things as to why we did this over another

Satisfying a subset of identified requirements was attractive to team members

A 100% requirement is an ideal requirement, but if you can't do 100%, i.e., sell, maintain....For my real product I may want to build only 60%

I think If we come up with a project that addresses 90% of that (CRKJ) we'll blow them away

Individuals identified more with some requirements than others

In some cases, people will say 'I don't know what this statement is.' We've had some that meant more to some people than others

"I'm not sure what you mean by tracking. It's unclear to me; is it clear to you?" "No, this is one I wish R was in the room because he had a lot of strong opinions on this."

Objective clarity focuses efforts

Clear requirements direct efforts

Requirement clarity promotes focused development effort

Knowing the requirements you can make a real product specification

If you create a new product, it's efficient because the first solution you get is optimized

Defined criteria promote focused progress

When you don't have rules, you can go in the wrong direction

I'd have a hard time eliminating more (ideas) than one or two without clear criteria

Customer empathy builds customer orientation

By getting into the customer's mind, they understand the product's utility

Getting oriented to customer needs. In some cases changing biases and getting intimately familiar with customer requirements and environments

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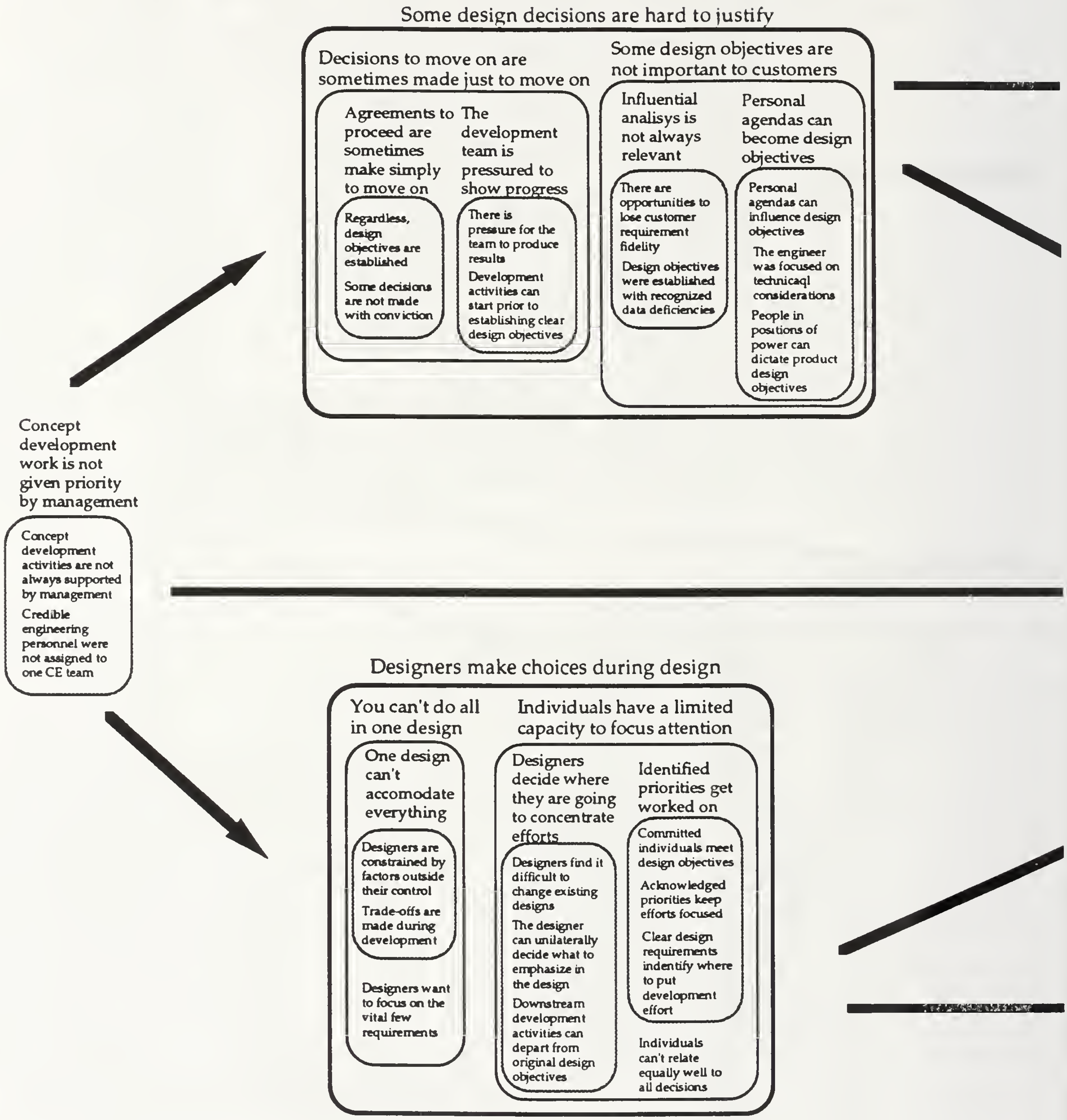
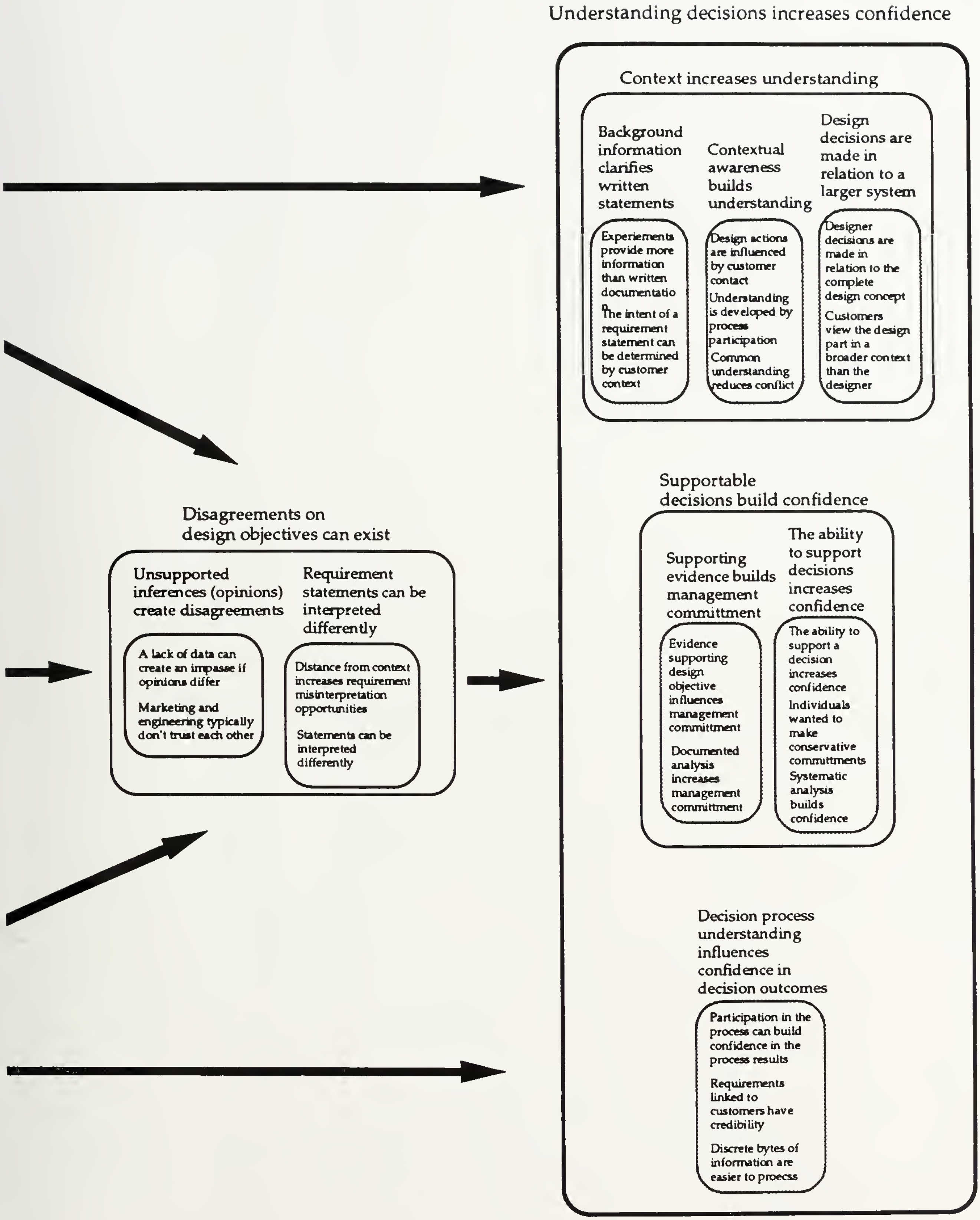
Gary Burchill

What have I observed about design objective clarity?




Understanding decisions increases confidence
Context increases understanding
Background information clarifies written statements
Contextual awareness builds understanding
Design decisions are made in relation to a larger system
Experiments provide more information than written documentatio
n
The intent of a requirement statement can be determined by customer context
Design actions are influenced by customer contact
Understanding is developed by process participation
Common understanding reduces conflict
Designer decisions are made in relation to the complete design concept
Customers view the design part in a broader context than the designer
Disagreements on design objectives can exist
Unsupported inferences (opinions) create disagreements
Requirement statements can be interpreted differently
A lack of data can create an impasse if opinions differ
Marketing and engineering typically don't trust each other
Distance from context increases requirement misinterpretation opportunities
Statements can be interpreted differently
Supportable decisions build confidence
Supporting evidence builds management committment
The ability to support decisions increases confidence
Evidence supporting design objective influences management committment
Documented analysis increases management committment
The ability to support a decision increases confidence
Individuals wanted to make conservative committments
Systematic analysis builds confidence
Decision process understanding influences confidence in decision outcomes
Participation in the process can build confidence in the process results
Requirements linked to customers have credibility
Discrete bytes of information are easier to proecss